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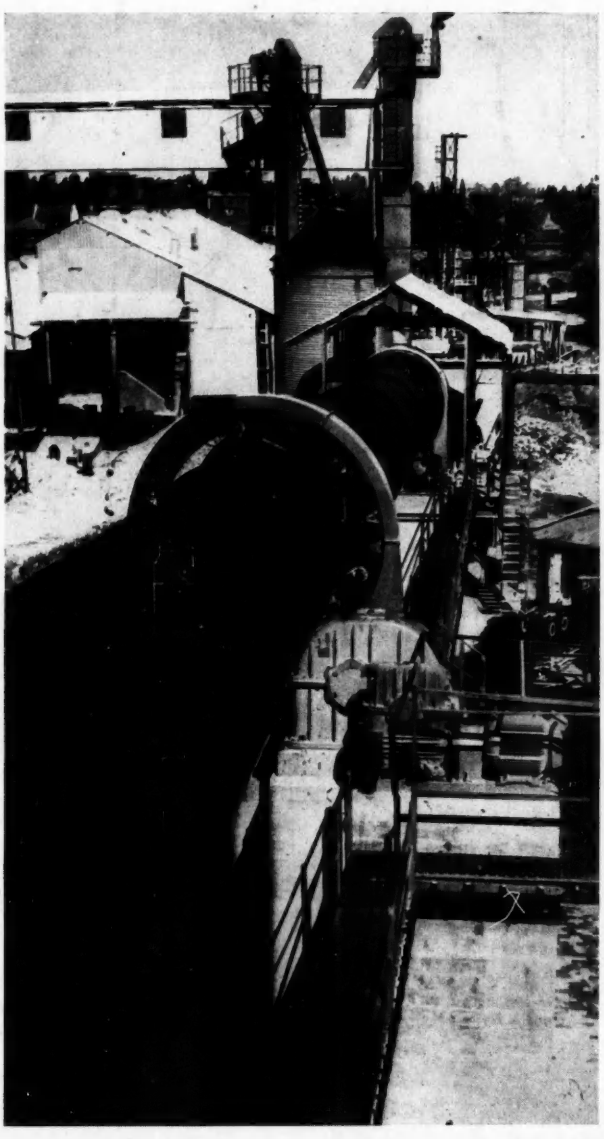

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## PRINCIPAL CONTENTS

(Complete contents on page 733)


**"Mileage not Verbiage"**.....733

**Urban Roads**.....734

**Helicopters in Amphibious Operations**.....734

**Vibration: A Survey of Industrial Applications**.....739
(J. P. DEN HARTOG)

**French Locomotive Experiences—No. II**.....736
(EDWARD H. LIVESAY)

**Road Transport and the National Economy**.....747

**Vacuum Techniques in the Atomic Energy Industry—No. II**.....749

**Light Weight Diesel Engines**.....754

**International Instrument Congress and Exhibition—No. I**.....764



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**INDEX TO ADVERTISERS**.....**PAGE 133**

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# THE ENGINEER

VOL. 204 No. 5313 NOVEMBER 22, 1957

CONTENTS

LEADING ARTICLES—
"Mileage Not Verbiage" ... ... ... 733
Urban Roads ... ... ... ... ... 734
Helicopters in Amphibious Operations 734

ARTICLES—
Automatic Trunk Telephones. (Illus.) 758
Channel Ports Motorway ... ... ... 735
Creep Tests for Materials on Gas-Cooled Reactors ... ... ... ... ... ... 759
Crossed-Roller Chains for Precision Slides. (Illus.) ... ... ... ... 761
Diesel Locomotive Maintenance Depot. (Illus.) ... ... ... ... ... ... 760
Earth-Moving Equipment. (Illus.) ... 751
Electrolytic Polisher. (Illus.) ... ... 762
French Locomotive Experiences. No. II. (Illus.) ... ... ... ... ... ... 736
Glass Factory at St. Asaph ... ... ... 760
High-Pressure Fuel System in R.M.S. "Queen Mary." (Illus.) ... ... 757
Highway Needs of Great Britain ... ... 745
International Standardisation of Rubber Test Methods ... ... ... ... ... 738
Light Weight Diesel Engines. (Illus.)... 754
Lloyd's Statistical Table... ... ... ... 748
Power Supply Stand-by. (Illus.)... ... 761
Professional Civil Servants ... ... ... 735
Railway Viaduct Inspection Equipment. (Illus.) ... ... ... ... ... ... 756
Refining Benzoles and Naphthas. (Illus.) 762
Road Transport and the National Economy... ... ... ... ... ... 747
Street Lighting ... ... ... ... ... 735
The British Council and Science ... ... 735
Training for Indian Supervisors for Durgapur Steel Works ... ... ... 748
Vacuum Techniques in the Atomic Energy Industry. No. II ... ... 749
Vibration: A Survey of Industrial Applications. (Illus.) ... ... ... 739
100 Years Ago... ... ... ... ... ... 734
800 h.p. Diesel-Electric Locomotive. (Illus.) ... ... ... ... ... ... 759

CONTINENTAL SECTION—
International Instrument Congress and Exhibition. No. I. (Illus.) ... ... 764
Evaluation of Variable Star Photographs. (Illus.) ... ... ... ... 765
Optical Strain Tester. (Illus.) ... ... 765
Portable Frame Bevelling Machine. (Illus.) ... ... ... ... ... ... 765

AMERICAN SECTION—
Richmond–San Rafael Bridge. No. IV. (Illus.) ... ... ... ... ... ... 766

LETTERS AND LITERATURE ... ... ... ... 752

LETTERS TO THE EDITOR—
Institution Meetings ... ... ... 752
Technology and Wisdom ... ... 753

BOOK REVIEW ... ... ... ... ... 753

NEWS AND NOTES—
Advanced Engineering Courses ... ... 770
British Patent Specifications. (Illus.)... 769
British Standards Institution... ... ... 748
Catalogues and Brochures ... ... ... 770
Forthcoming Engagements ... ... ... 770
Industrial and Labour Notes... ... ... 763
Launches and Trial Trips ... ... ... 770
Personal and Business ... ... ... ... 768

## "MILEAGE NOT VERBIAGE"

Last week Mr. Watkinson, the Minister of Transport and Civil Aviation, expressed his views at the Institution of Civil Engineers' highway conference (see page 745). We have been told the conference achieved nothing but verbiage, was merely a rehash of well-known facts and figures, and the speakers were preaching to the converted. That would not, in our view, be a just appraisal. Many of the difficulties discussed—such as the recruitment of young professional staff—will, we think, disappear when the road programme gets under way. But new facts were brought to light and the conference was, indeed, an appreciable step forward and has been of great value. First, note the Institution of Civil Engineers' opinion in convening the conference that "One of the major tasks of the civil engineer in the next decade or two will be to build new and to improve existing roads." Second, note the phrase we used just now: "When the road programme gets under way." There was a decided lifting at the conference of that atmosphere of frustration characteristic of such occasions over the past few years, when authorities on highway engineering have spoken convinced of the technical and economic justice of their cause, but equally convinced that nothing would be done about it. The conference met just after a crisis in the national economy, which, as we all know, has resulted in a policy of restricting all capital works; but it was also announced that the road programme would not be cut. All highway people were surprised; and Mr. Watkinson was surprised that they were surprised. So it now seems a good bet that the highway programme will get under way properly next year as planned. Perhaps it is not big enough, or courageous enough, to measure up to the needs, but even if not, it will be a good, large-scale start, and the position is thus more encouraging than we have been able to record before. As to the annual rate at which new roads should be built, and the cost of a complete programme, there was quite a lot to be learned from the conference.

It is planned that Government expenditure on new road schemes will amount to £280 million in the four years 1958/59 to 1961/62, an average of £70,000,000 annually. Expenditure on road transport, however, is running at well over £2000 million per annum, and represents about 13·5 per cent of the national income, so the expenditure on new roads will be at a rate approaching 4 per cent of the "turnover." In his paper investigating the needs of a national highway programme, Mr. James Drake estimates that a minimum expenditure on new roads of £75,000,000 per annum would be necessary, thus giving a measure of confirmation to the official view, though Mr. Drake also suggests a minimum total figure for expenditure of £175 million per annum (at present about £75,000,000 per annum is spent on maintenance). However, in another paper, Messrs. Nicholas and Wilkes assess in some detail the cost of bringing the entire highway system—minor and major roads alike—to a passable standard of adequacy. The grand total of all the categories they investigate—urban roads, motorways, &c.—is £3500 million, which they relate to a twenty-year period of development, inferring an annual investment of £175 million, which is not comparable to Mr. Drake's figure, since maintenance must be added to it. This expenditure is considered conservative in some ways, and it still represents an investment of less than 10 per cent of the annual expenditure on road transport. The total also compares with a figure of £5000 million, quoted for the nationalised fuel and power industries—coal, gas and electricity—up to 1965. In summing up the conference, Sir Herbert Manzoni pointed out that traffic would double in ten years, and the road programme should thus relate to the same period, and he urged an expenditure running at £350 million per annum over ten years. His estimate is probably the most realistic one.

A comparison of these various figures will, we think, lead to the opinion that a good start will be made by the Government's programme, if the average rate of expenditure suggested over the four-year period is reached in the early part of that period; but it must be expanded rapidly thereafter, if the needs are to be met. The benefits felt from the new roads, as they come progressively into use, will then, we think, convincingly demonstrate the wisdom of such investment, and pressure

to accelerate the programme will result. There remains, however, one aspect of the road problem more thorny and intangible than the rest which we discuss below; that is, the urban road and urban traffic.

### URBAN ROADS

If any criticism were to be made of the conference at the Institution of Civil Engineers, discussed above, it would surely be that only one paper, out of a total of ten, dealt with urban roads. It was generally conceded that factual information on urban road problems was too scarce to allow a proper appraisal of the needs. Increasing insight into the economic and technical factors of new road construction is being gained, as the abstracts from the conference given in this issue clearly show, but the urban problem has to some extent defied exact analysis up to now. More surveys and more factual knowledge will doubtless be accumulated to change this situation, as time goes on. The difficulties are not entirely technical, however, and it is evident that a change of outlook needs to be brought about, in the mind of the man in the street, as well as in the judgment of engineers, of town planners, and of architects. Even about motorways a period of adjustment was needed, before people came to recognise that such a road—with all its paraphernalia of restricted access and dual carriageways—was something vastly superior to the common or garden roads they experienced in their daily lives; indeed, that lesson will not be properly learned until we have an appreciable mileage of motor roads in actual use in this country. But it has been learned by those more responsible persons who influence public policy. The next step is to bring about the recognition that even in the centre of a large town the same advantages apply, and that the urban motor road is an inevitable addition to our national scene.

Mr. Nicholas, the city surveyor of Manchester, proposed three maxims when introducing his paper on urban highways, namely (i) no frontage having access to the road, (ii) no traffic lights, and (iii) no pedestrians. It was interesting to hear intense opposition at the conference from speakers who serve on city councils. They pointed out the value of such frontages for rating. Without the income from these rates, they argued, the road could not be financed. If that argument is accepted, the problem of financing may indeed be solved, but the money spent will, equally, be wasted, since the full traffic capacity of the road will not be achieved, and delays and accidents will again result. Rejection of this argument implies a new attitude to town planning. The areas served by an urban motor road could be arranged conveniently and attractively, so that high rates could be gathered, traditional atmosphere retained, and amenities enhanced, by measures such as parking capacity, and the grouping of centres of activity into traffic-free enclaves. Building an urban motorway is not itself a complete solution; examples in the United States demonstrate the point. That is why the problem needs to be grasped equally by those responsible for city planning and by architects. The urban motorway will serve a city in this way, not dominate it; but its presence is essential because of its traffic capacity. Road widenings and piecemeal improvements are far more expensive and much less effective.

The first of these schemes within the urban motor road category is already under construction in this country; it is in Lancashire, under the charge of Mr. Drake, and includes the high-level bridge crossing the Manchester Ship Canal at Barton. Proposals for urban roads of this nature have also been made for Manchester (as explained at the conference by Mr. Nicholas) and for Birmingham, and it is obvious from the statements made by the respective city engineers at the conference that both of these cities are alive to the problem. The greatest task of all, however, lies in London. It was a great disappointment that a paper on road proposals for the metropolitan area could not have been given to the conference, or even that London's problems could not have shared in the discussion. One fact, however, can be recorded. Mr. Watkinson stated that he had set up a London roads committee, comprising representatives of his Ministry, the L.C.C. and the Road Research Laboratory, "to work out farsighted programmes of road works for the next twenty years." May we hope that its proposals, unlike those of committee after committee for the last fifty years and more, will not be merely put on the shelf.

## The Engineer

### 100 Years Ago

(NOVEMBER 20, 1857)

"RENEWED ATTEMPT TO LAUNCH THE LEVIATHAN"

"Another attempt yesterday made to launch the Leviathan was unfortunately not successful. In this instance the cause of the failure is very soon told, namely, that the pileing against which the hydraulic rams were struted gave way, and so prevented any great force being brought to bear upon the cradles. So secretly had all the preparations been made for this renewed attempt to launch the vessel that not more than twenty to thirty persons were present, they being mostly engineers or shipbuilders. Men are now busily engaged in re-driving the pileing against which the rams will be again placed, and the work will be continued both day and night until completed.

"We look upon the present accident as one of very little consequence inasmuch as the pileing was never designed to withstand any great strain backwards, that is, towards the shore, but rather to resist the far greater strain which it was fairly presumed would be brought upon it in the direction of the river.

"At the first attempt, it will be recollected, only two rams were employed, one at each cradle; on the present occasion six rams were used—two seven-inch ones at the aftermost part of each cradle, and one ten-inch at the foremost part. The attempt to launch was about one p.m., but, owing to the accident above stated, it was soon abandoned. In addition to the breakage of the pileing, the down-haul chain at the bow of the vessel gave way, but this will of course be promptly repaired. There is nothing, therefore, in the present failure to cause much regret, as what damage is done can very easily be put right. We believe nothing has been done towards altering the principle of the mode of launching originally decided upon, but we presume every care will be taken to keep all hands clear of the winch-handles whose unexpected(?) motion was the cause of the fatal accident, which happened upon the first attempt to launch the vessel. It is to be hoped that perseverance in the 'trial and error' principle will at length result in the successful floating of the Leviathan.

### HELICOPTERS IN AMPHIBIOUS OPERATIONS

With the recent withdrawal of the battleships "Iowa" and "Wisconsin" from the United States active fleet, U.S. naval Task Forces will all henceforth consist of aircraft carriers, cruisers and supporting ships. This is also the basis on which the Royal Navy is to be organised in the future. But with only seven modern fast carriers available and with the contemplated reduction in the number of cruisers in the active fleet, we shall be able to maintain in commission at the most only four Task Forces, each consisting of one carrier and two cruisers with their supporting ships. The main purpose of this new organisation is to bring power rapidly to bear in peacetime emergencies, and limited hostilities, and it is thus very satisfactory that the Admiralty, as a result of the Port Said operations, is now attaching great importance to the value of Royal Marine Commandos landing from helicopters in operations of this kind. In the Port Said landing not only was the main aircraft support provided by naval aircraft from carriers, but the two 24-knot "Glory" class carriers, "Ocean" and "Theseus," operated some twenty-four "Sycamore" and "Whirlwind" helicopters, in positions a few miles off the coast, from which over 400 Royal Marines and 20 tons of stores were landed in an hour and a half. Plans are now being prepared for the conversion of one of our existing carriers—probably the "Glory" class "Warrior," which would be of little value for front line operations in a major war—for maintaining and operating about twenty of the Westland "Wessex" helicopters, now on order for the Admiralty, each capable of carrying fifteen men with their fighting equipment. The carrier will be able to embark a complete Commando of 600 Royal Marines as and when required for exercises or operations.

There has, in fact, been a marked change in the role of the Royal Marines since the war. In the past the corps were

mainly employed as part of the ship's company of large ships—manning one of the main armament turrets and two of the 6in guns of a battleship—though trained also as soldiers for landing from the fleet in an emergency. Under modern conditions there is less need for Marine detachments in ships and the number still at sea in carriers and cruisers is gradually being reduced. Commandos have become the most important element in the corps, available and ready as the first troops to be landed in amphibious operations. This is in line with what has always been the role of the United States Marines, who are trained and organised as a self-contained force available for emergency in any part of the world. The United States Navy has for some time been practising the landing of marines by helicopter from a converted carrier and the construction of a ship specially designed for this work—a helicopter assault ship to carry twenty large helicopters and 2000 marines—will be begun in the near future.

In developing the helicopter landing technique and building helicopter assault ships, the Americans have, however, in mind a major war rather than "peacetime emergencies and limited hostilities." Concurrently the United States Bureau of Ships is devoting much attention to the development of improved amphibious personnel carriers—"landing vehicles, tracked," commonly called LVT—in an endeavour to eliminate the deadly beach landings which resulted in such heavy casualties to their marines in World War II. Experiments are also in progress in the United States with four-rotor helicopters. It is hoped that the use of four small rotors and simpler rotor hubs will result in greater and more rapid response to the movement of the pilot's controls and will permit of easier loading without the careful positioning required in conventional helicopters. Finally, the Americans have designed a new type of airborne armament for conventional helicopters to protect assault troops from harassing enemy fire. These new helicopter weapons are called ground fire suppression kits and are of two kinds. One consists of two rifle-calibre machine guns, which can be attached to either side of a helicopter and controlled by a hand-grip firing mechanism within the cockpit. The other is a fixed unit which also consists of two machine guns, but is supplemented with eight 3·5in rockets. Each weapon unit is so constructed that assault troops could, if necessary, remove the machine guns and ammunition from their mountings and use them as regular field weapons. There can, indeed, be no doubt that besides their other naval and military uses, helicopters will be much in demand for amphibious operations in the future in the event of either a local or major war.

# A Seven Day Journal

### Professional Civil Servants

THE Institution of Professional Civil Servants has expressed its concern at what it describes as an "astounding decision" of the Ministry of Works. The Ministry has announced the forthcoming retirement of Sir Charles Mole, Director General of Works, and has stated that the position will not be filled, for the time being at any rate; instead a non-professional general manager will become responsible for the organisation, co-ordination and direction of the work of the Ministry's directorate general. The Institution's criticism is that, in an age of increasing technical complexity, a department which is probably the biggest organisation in the world engaged in building construction and maintenance "no longer needs to be led by a professional officer." In a statement setting out its views, the Institution points out that the Ministry of Works, with a responsibility which is primarily professional in character, has an overall staffing of 60 per cent clerical and administrative officers and only 40 per cent professional and technical officers. Now, the statement observes, "it is to be shorn of its professional head."

The statement goes on to say that the Institution of Professional Civil Servants has asked the Minister of Works to receive a deputation, for it finds it difficult to believe that the Government really intends to maintain the decision not to appoint a professional officer as Director General of Works. In industry and commerce the emphasis is on the increasing appointment of technically qualified officers to posts of management. The efficiency of the Ministry of Works requires the appointment of a professional head, and the Institution's hope is that further consideration by Ministers will lead them "to reverse so thoroughly bad a decision."

### Channel Ports Motorway

THE proposed route of a motorway 25 miles in length and by-passing the Medway towns on the A2 route from London to Canterbury and Dover, has been published by the Ministry of Transport and Civil Aviation. Mr. Watkinson's statement of his priorities for road schemes, given at last week's conference, is printed on another page of this issue; it will be recalled that this route, dubbed the channel ports motorway, was assigned a high degree of priority by him, indirectly because of the importance attached to the European Free Trade Area. Objections against the proposed route can be lodged during the next three months.

Dual 24ft carriageways and motorway standards generally will characterise the new road. As proposed, it leaves the A.2 just outside Strood, runs to the south of the existing road and rejoins it at Brenley Corner, east of Faversham, where A.299 branches from the A.2. There will be four intermediate "interchanges." The level of the road will vary considerably, rising to 600ft above sea level. Where it crosses the River Medway, the bridge will have to be about 100ft above water level and will be an imposing structure with a main span of about 500ft and approach viaducts on either side; it is expected to cost over £2,000,000. The Stockbury Valley will have to be crossed at a height of some 70ft above ground.

Messrs. Freeman, Fox and Partners are the consulting engineers for the motorway and Mr. Robert F. Earley, consulting engineer, will be associated with them. The cost of this 25-mile route is at present considered to be of the order of £10,000,000.

### The British Council and Science

IN its annual report for 1956–57, the British Council emphasises that one of its principal tasks is to make known British scientific achievement. The report comments on the "widespread attention and respect for Britain" secured by the publicity overseas about the Calder Hall nuclear power station, and says that such publicity needs to be supplemented and supported by less spectacular, patient, long-term work directed to providing a sustained flow of information to the appropriate professional groups.

The report goes on to say that since 1950 the number of overseas students in the United Kingdom has risen from 10,000 to nearly 35,000, about 60 per cent of them being concerned with the sciences. Even so, it is stated, the extent to which Britain is regarded as an international centre for the study of science and technology cannot be measured solely in terms of the number of students actually here. Many more might well come if their countries could find the funds to send them or if Britain could offer scholarships and places on the scale of some of the other countries competing in this field. Attention is drawn, however, to the advantage which Britain shares with the Commonwealth and the U.S.A. in that the English language has become established among scientists as an essential means of communication.

### Street Lighting

IN a paper on street lighting, read last week to the Association of Public Lighting Engineers, in Dundee, Mr. W. Robinson asserted that advance with street lighting was not fast enough. There was reason to question, he said, whether the advance was on the right lines. The average rate paid per person was approximately £15; of that the total paid out for unsubsidised street lighting was 8s., or less than 3 per cent of rate income. It was against the financial background, Mr. Robinson commented that the steadily rising proportion of accidents at night must be scrutinised.

The main safety role of street lighting, Mr. Robinson went on to say, was the protection of pedestrians who were the most vulnerable of all road users. During the first eight months of this year, night-time road casualties had risen 5·8 per cent, while day-time casualties had dropped by 2·3 per cent. In a reference to disputes between ratepayers' organisations and local authorities, Mr. Robinson remarked that lighting authorities and engineers tended to think of street lighting too much in terms of efficiency, light distribution and electricity cost and too little in terms of the people who lived with it and moved by it. Certainly some continuity of the standard of lighting along traffic routes was wanted, but continuity did not have to mean uniformity. The real future for street lighting would start, Mr. Robinson suggested, once it was decided that safety, security and pleasure from the roads and streets after dark was worth a better slice of the local and national cake!

# French Locomotive Experiences

By EDWARD H. LIVESAY

## No. II—A HIGH-SPEED TEST RUN

(*Continued from page* 701, *November* 15)

IT is common knowledge that the S.N.C.F. intends to electrify its whole system, and that steady progress is being made to this end, particularly in the N.E. Region, which is highly industrialised, with a network of lines serving factory and mining areas, besides carrying heavy traffic to and from Belgium and the Saar.

Much of the freight movement in this region is already handled electrically, particularly eastward from Valenciennes; the next stage will concern passenger services, which are to be electrified shortly and run at high speeds, up to 100 m.p.h.; one of the first routes over which these trains will operate is that between Paris and Lille. With the changeover from steam to electric traction coming about in the near future, it has been considered necessary to carry out experiments with new equipment that will be called for, and numerous test runs have been made with this end in view. One of the most important investigations has been the perfection of pantograph and catenary gear for the high speeds contemplated, and on Monsieur Chapelon suggesting that I might like to take part in one of the test runs being made to try out these features, it is hardly necessary to say the invitation was accepted. with alacrity, as the experience was sure to prove both novel and interesting; also pleasant, as my friends Messieurs Leseigneur and Fillon would be associated with it in the same capacities, driver and interpreter respectively, that they had so pleasantly and capably undertaken for me on other occasions and with whom I had ridden many times. *Mais revenons a nos moutons.*

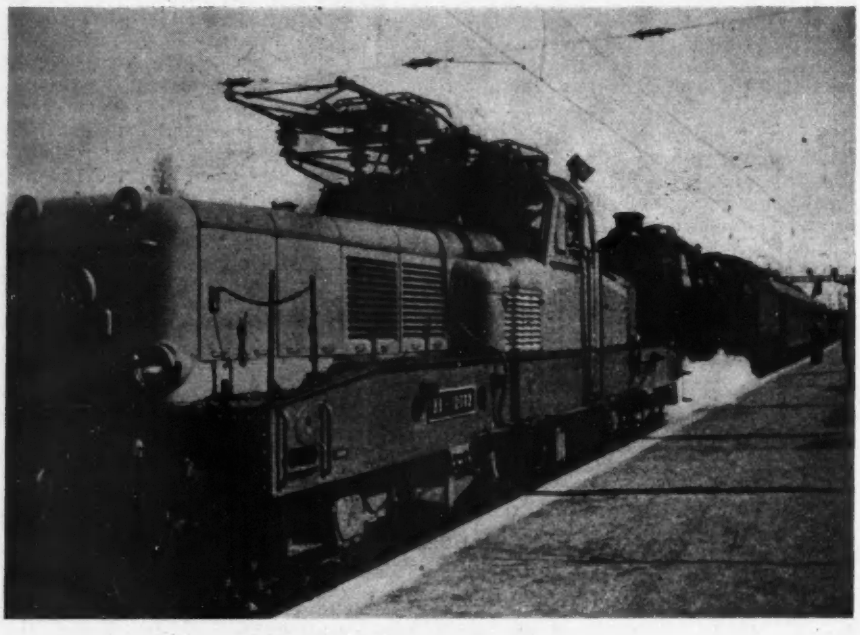

Fig. 5—Test train at Aulnoye

It was considered necessary by the technical staff of the S.N.C.F. that improved pantograph and catenary apparatus should be developed for high-speed passenger locomotives, the normal type—presumably that at present used in freight traffic—being only suitable for speeds up to 75 m.p.h., whereas the 100 m.p.h. speed that would be reached in ordinary operation between Paris and Lille made better conditions of current collection and catenary action essential. Further, before coming to a final decision as to the best type to adopt, it was advisable to compare different designs of French and foreign pantographs—Swiss, Swedish, German, and Austrian—while keeping within the framework of tests undertaken by the Department of Studies of Electric Traction, S.N.C.F., on behalf of the Research and Studies Bureau.

As the trials were essentially to measure and record the behaviour of pantograph and catenary apparatus, as well as the quality of contact achieved, current could not be passing while the tests were being made; the electric locomotive must necessarily be run "dead-headed" and a steam locomotive used to propel the former and haul the recording and brake cars while the pantograph is under observation. It is also essential that the electric locomotive be in its proper position at the head of the train during the tests if normal conditions are to be simulated, as the pantographs are considerably affected by air currents at high speed. The electric engine, which may be one of two types, with central or double frontal cab, is therefore pushed by the steam locomotive, this in turn hauling an electrotechnic car fitted with the necessary recording apparatus. At the rear is a passenger coach, added to increase the braked weight of the train, one suitable for the 100 m.p.h. attained during the tests, having a high brake ratio. It would have been advantageous if more than one coach could be utilised, even several, but the increased weight of the train would then reduce the acceleration essential where the tests have to be made over a limited length of track, as is the case between Aulnoye and Valenciennes.

The test train (Fig. 5) is made up as follows:—

| | Tons |
|---|---|
| Electric locomotive: | |
| BB 12000 | 127 |
| or | |
| BB 9000 | 85 |
| Propelling engine: | |
| "Pacific" 4–6–2 | 180 |
| Recording car | 50 |
| Brake car | 48 |

The total weight of the train is therefore either 225 tons or 183 tons, depending on which type of electric locomotive is under test.

For the purpose of these tests it was necessary to choose a stretch of electrified line having both long straights and a profile permitting quick acceleration, and the Aulnoye/Valenciennes section fulfilled these desiderata, the maximum gradient being 1 in 100 (Fig. 6). The choice of a propelling engine called for a sufficiently powerful machine capable of attaining 100 m.p.h. without risk of mechanical failure, and one with axle weights not exceeding the permissible limits at this speed over the line in question. The choice fell on the "Pacific" locomotives formerly running on the Paris/Orleans line, modified by Monsieur Chapelon in 1934, and now classified as Series 231E, Nord Division. Tests dating back to 1935 had demonstrated the excellent behaviour of these engines up to 108 m.p.h.; in fact, they were the only engines capable of these performances when acting as propellers, with the exception of the 4–6–4 four-cylinder compound "U1" (THE ENGINEER, March 5, 1954, and September 7, 1956). Unfortunately—from the writer's point of view!—this fine engine could not be used owing to the weight, 22·5 tons, carried on the driving axles; the "E" class "Pacifics" have an axle weight of 18 tons, and are normally limited to 87 m.p.h. They were illustrated by Figs. 3 and 4, with the principal dimensions appended, in article No. I last week.

The engines used for these runs were given no special preparation, beyond ultrasonic tests on, and examination of, the tyres, and the installation of Flaman recorders registering up to 100 m.p.h., about 15 m.p.h. higher than the normal pattern. Out of ten 231E engines belonging to the Fives (Lille) Depot which have provided the motive power for the numerous tests, three have been used in succession without any untoward incident being recorded to date; the three are:—Winter, 1955–6, No. E35, driver Jacquet and fireman Gremillier; spring/summer, 1956, No. E29, driver Olivier and fireman Legrand; autumn, 1956, No. E19, driver Vernet and fireman Ollivier.

Eight runs were carried out at 100 to 105 m.p.h. by each of the first two engines; E19, on which I rode, has been used for more numerous tests, actually over twenty, at the above speed, and undertook a new series beginning in December, 1956, of which particulars are not available at present for inclusion in this article.

The usual test conditions are as follows. The train leaves Aulnoye at 18·5 m.p.h., immediately running into a restriction of 37 m.p.h. extending until Berliamont junction is cleared. Advantage must then be taken of the short drop of 1 in 100 approaching Berliamont station—see profile—to obtain quick acceleration. From the graph it will be seen that the speed rises to approximately 60 m.p.h. at the foot of the incline, down

which the regulator is full open, and the cut-off 45 per cent in both h.p. and l.p. cylinders. Along the slightly falling stretch towards Locquignolat (km 74·5) the speed increases, reaching 75 m.p.h. by km 72 and 87 m.p.h. before beginning the 1 in 100 descent between Jolimetz and Le Quesnoy. On passing the latter station the cut-off is shortened to 40 per cent in both pairs of cylinders in order that 94 m.p.h. may not be much exceeded until, a little farther along, the cut-off is lengthened, if desired, in order to reach 100 m.p.h. as quickly as possible. In practice, taking advantage of a short drop of 1 in 111, this speed is often reached between km 65 and km 64.

Down the Ruesnes gradient the tractive effort is decreased to ensure that nothing much over 100 to 105 m.p.h. is done, figures show the speed at the kilometre points from 76 to 57, and by comparing them with the profile it is easy to form a very graphic picture of the train's performance.

| Km | m.p.h. | Km | m.p.h. | Km | m.p.h. |
|---|---|---|---|---|---|
| 76 | 63·0 | 69 | 87·6 | 62 | 102·6 |
| 75 | 62·5 | 68 | 93·2 | 61 | 105·6 |
| 74 | 68·5 | 67 | 93·2 | 60 | 104·4 |
| 73 | 72·7 | 66 | 95·7 | 59 | 102·6 |
| 72 | 77·0 | 65 | 99·4 | 58 | 97·0 |
| 71 | 82·0 | 64 | 100·0 | 57 | 88·8 |
| 70 | 86·4 | 63 | 100·5 | | |

It will be noticed from the above figures that the speed nearing the end of the run was higher than planned—the "working timetable" was bettered somewhat. This was also the case during the run of which I was an observer; the Flaman needle crept steadily up to the 100 m.p.h. mark and there stuck, but it seemed to me that the speed

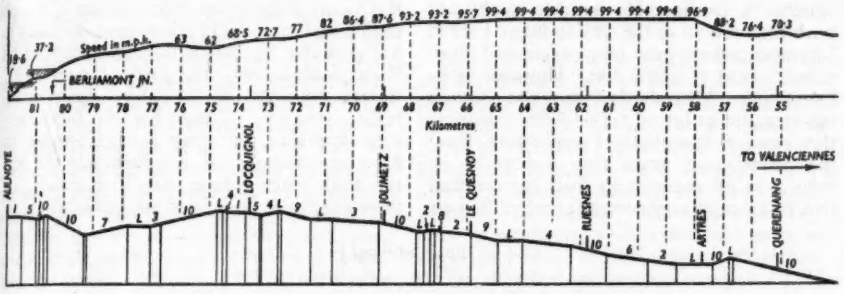


Fig. 6—Planned speed graph for tests and gradient profile

by partially closing the regulator; on passing Artres station steam is shut off and brakes applied to reduce the speed to 75 m.p.h. for the negotiation of curvature near km 56·5.

During the tests smokebox vacuum is generally about 200mm, though sometimes it reaches 250mm, and superheat rises to 752 deg., despite a low fire. The boiler must steam freely and continuously to satisfy the demands made upon it, notwithstanding that a large fire cannot be built up for a run of only 35km when the regulator must be shut 22km from the start. The water level must be kept fairly high on account of the 1 in 100 down gradients encountered, yet it must not be too high to avoid risk of priming at the speeds reached, which call for full regulator and 45 per cent cut-off. The 231E class engines have fully realised all these requirements and have shown surprising driving flexibility. The winter tests with E35 were particularly successful as the air temperature frequently fell below 23 deg. Fah. and sometimes fairly strong winds further hampered performance. Incidentally, wind, whether head or side, creates another difficulty, inasmuch as the presence of the electric locomotive in front almost completely cancels the efficacy of the smokebox side deflectors, with the result that exhaust fumes, blowing into the cab, cause serious inconvenience to the people on the footplate; I noticed this too, but was quite willing to put up with it under circumstances so interesting. Engine No. E19 was built in 1913 by the Fives-Lille Company, rebuilt and modified on Chapelon principles in 1934 at the Tours shops; Nos. E29 and E35 were built in 1936–7 by the Forges et Acieries de la Marine et Hommecourt on the same improved lines as No. E19.

As a Flaman recording only gives an approximately accurate graph of the speed, though fairly close, an Amsler table recording of the first run, made on April 4, 1956, from the dynamometer car—or the equivalent electrotechnic car—is appended; engine No. E29 was the propeller, the run being made against a head wind of 10 m.p.h., the air temperature being 59 deg. Fah. The still increased a trifle after this—it probably did. The maximum, above 105·6, was touched on 1 in 100 down, east of Reusnes.

The profile shows plainly the suitability of the stretch of line chosen for the tests, the highest speed being reached on approximately level or falling track; on the run being completed, the upward piece of 1 in 100 at km57 is useful as a reminder to begin braking and helps considerably, no doubt, in speed reduction. It should be remembered, however, that the tests are an investigation of pantograph, not locomotive performance, though, to me—and I hope the reader—the latter is the *raison d'être* of this article and of greater interest. I was on the steam locomotive, not the electric, and apologise to the officials concerned for admitting that the behaviour of the pantograph did not concern me; I forgot all about it! I am sure that, in any case, both Monsieur Chapelon and Monsieur Leseigneur will fully enter into my feelings and sympathise—they are "steam" men too!

Having explained the object of the trial run, its venue and the composition of the train, next in order comes a description of one of the tests during which I was enabled to act as observer, thanks to the kindness of Monsieur Segaud and other officials of the S.N.C.F. at the instigation of Monsieur Chapelon, though he is no longer directly connected with the railway. We—Monsieur Leseigneur, Monsieur Fillon, and myself—left the Gare du Nord in the cab of one of the outstanding "P" class 4–8–2 engines, but this opening move in the day's experiences will be dealt with in the following article; it is sufficient to say here that Monsieur Leseigneur was at the regulator, with Monsieur Fillon acting, as usual, cicerone to me, and that both continued in the same positions throughout the day. It was unfortunate that the weather was bad, both raining and blowing strongly, making photography impossible, but it showed that these tests are carried out under all and any climatic conditions, which is as it should be; after all, the gear to be tested will have to work satisfactorily under similarly diverse circumstances, no matter what meteorological hindrances are encountered.

Dismounting at Aulnoye, where, needless to say, we arrived on time, we had only a few minutes to await the appearance of the test train, which was made up of the four vehicles arranged as described; the weather was as unpleasant as ever, wet and blustery. The motive power was provided by the ex-Paris/Orleans "Pacific" No. 231-E19, built 1913, rebuilt with Chapelon improvements in 1934; the enginemen were Messieurs Vernet and Ollivier. It speaks volumes for the engine and everybody concerned in its design and subsequent refinement that, though forty-three years old, it had been chosen for this strenuous test run, and had already done many similar ones satisfactorily; this seemed to me the outstanding feature of the business. It is unnecessary to enlarge on the points that enable these engines to do such remarkable work; this has been the subject of previous articles, so I shall merely mention that they chiefly underline the benefits of unrestricted steam flow from the boiler through cylinders to exhaust outlet, a high degree of superheat and compound expansion controlled by poppet valves; also feed water heating. One has only to experience and watch their work from the cab to appreciate it; the more I travel on them the greater becomes my regard for them.

As there is none too much room in the cab of these "Pacifics" and there were five of us there, Monsieur Leseigneur placed me close beside and behind him, the best position from which to keep a roving eye on the boiler and steam chest gauges and the Flaman recorder in front of him; the other three occupants were mostly on the other (right) side of the shovel-plate, on French engines commendably big and forward-projecting. There are several things I would have liked to watch—cut-off scales (two), exhaust pressure gauge, and so forth—but it did not seem likely that due attention could be given to all these during such a short trip at superspeed, while making notes and holding on at the same time. In addition, 'phone and loudspeaker communication with the instrument car were very much in evidence, Fillon yelling his interpretation of the messages when they were of value to me. There was certainly not going to be any time to day-dream; my notes are, to say the least, scrappy, incomplete and largely exclamatory, but such as they are, must serve; the Flaman seems to have come in for most attention.

The start took place at 10.52, with moderate acceleration—I was not aware at the time of the 37 m.p.h. restriction to Berliamont Junction—for a mile or so; then it became very rapid, on full regulator, and judging from the exhaust, unusually staccato for a compound, generous valve travel, was utilized though the gradient was obviously favourable. I had not got a profile either—should not have been able to follow it if I had! I soon found it almost impossible to do much more than hold on by an arm round the rear post at the cab-side, and make spasmodic notes, which are only just decipherable; these I will quote verbatim. "Start 10.52—no slip—acceleration moderate—soon full reg.—cut-offs (?)—'phone—rapid acceleration—speed in about 3 miles 100km—is steamer doing all work? (It was.)—Still accelerating 130—140—riding roughish—not too bad!—150—160—160 plus—several miles top speed—riding rough for French—steamer doing all work—rolling, some nosing—smoke in cab nuisance—straight track—reg. shut, braking for curve,"—after which there are no more notes, so apparently we stopped. A

poor lot, granted, but—*Je vous fais mille excuses!* The experience was novel, the run short; there were too many things to watch simultaneously, and they happened so quickly, plus complicating sensations, physical and mental, that it is scarcely to be wondered at that I rather fell down on the job. Subsequently, down on terra firma, inquiries brought out that the regulator had been full open throughout and the cut-off 45 per cent in both h.p. and l.p. cylinders, until it was necessary to reduce speed near the finish—or moderate it to prevent excess—when it was shortened to 40 per cent. I did not attempt to note pressures in boiler, steam chests and exhaust because—with the exception of the latter—they were sure to be right where they should be. A Chapelon engine doing an important test run in the hands of an expert crew—of course, pressures would be right! But I do wish having noted the exhaust pressure; it would have been interesting to have it; in a Kylchap double blast pipe, from l.p. cylinders at 45 per cent cut-off and full regulator while the engine was doing over 100 m.p.h., I have no such figures in my archives—other people might be interested, too!

This run gives a perfect demonstration of unexceptionable steam flow and "front end" arrangements—a compound engine making over 100 m.p.h. with 45 per cent valve travel—no signs of wire-drawing or exhaust throttling there! Ease and freedom everywhere and no knocking, though full regulator had been used throughout. Incidentally, Monsieur Chapelon afterwards mentioned to me he had thought it possible that running these engines considerably over the 87 m.p.h. designed speed might result in valve trouble—these are of the Dabeg oscillating poppet type, Walschaerts operated—but nothing untoward had occurred. Presumably this meant that bounce might take place—the rockers not following the cam contours closely at maximum speed—this is my interpretation of his meaning. At top speed the driving wheels were making about 460 r.p.m., which is a good deal to ask of a forty-three-year-old engine—or any engine—which had already made fifteen similar runs, and was to make further runs subsequently; everything about it, including the valve-gear, must be very good to stand up to such demands. Comparatively, when the Gresley Pacific "Mallard" made the well-known record run in 1938, reaching 125 m.p.h., that engine's driving wheels were revolving even faster than this, but maximum speed was only touched for a few hundred yards, and the engine was practically new. It was mentioned to me by an official very closely connected with the run that "she was shaken pretty badly"—his words. I decline to say who this was, for obvious reasons, but it seemed to me very probable, as no engine with 6ft 8in wheels can be expected to do 125 m.p.h. with impunity. The German 4–6–4, which also reached 125 m.p.h. about the same time, had 7ft 7½in wheels, and was designed specifically for the highest speeds. In addition, both the Gresley and German machines were streamlined and—I believe—the trains they were handling were streamlined also, which makes a good deal of difference. E19 had none of these easements and the run was merely one out of many, all made without special preparation or ill effects.

Curiously enough, perhaps the thing that always comes into my mind when recalling this experience was one of no real importance under the circumstances—the riding, which was certainly on the rough side! Not that this is in any way derogatory, but it was unexpected, the beautiful action of all the many French engines on which I had ridden having always so impressed me. No doubt the presence of the 120-ton dead electric locomotive in front had a lot to do with it, any "tail-wagging" of the latter intensifying whatever nosing No. E19 might have been indulging in, thus making confusion worse confounded. But I can assure the reader that E19's fretfulness did not approach the bad behaviour of some British engines on which I have had the misery of riding, and they were not doing 100 m.p.h. or anything approaching it.

Thinking over this test run and of the engine which powered it, one cannot help having doubts whether the wholesale scrapping of inefficient, mediocre B.R. locomotives during recent years and their replacement by "Standard" designs was altogether necessary or economical; one wonders whether a considerable number might not have been rebuilt in the way so many French locomotives have been rejuvenated and given a fresh lease of useful life. However satisfactory the "Standards" may be from a maintenance point of view—I am assuming they are—or from that of availability, from the performance angle they appear to be little if at all superior to their forerunners. One instance of very successful rebuilding on B.R. does come to mind—the "Merchant Navys"—giving point to this suggestion; my all too brief experience of one of these was simply delightful and enabled me to say without peradventure: "This is the first engine I have ridden for years in Britain with which I can find no fault whatever!" I made no secret of this at the time, nor since; that rebuild has been a success, at any rate. Others might have been, too.

So much for this very interesting experience on a forty-three-year-old locomotive making over 100 m.p.h.; it was followed by a pleasant lunch at Aulnoye with everyone concerned, who went out of their way, as French railway officials always do, to make me welcome. I had been given the choice of returning to Paris by "Autorail" or on the same fine "P" class 4–8–2 ridden to Aulnoye in the morning, with the same crew. Needless to say, I chose the latter—when I like an engine and crew I like them—one contact is not enough. So that is how we returned to Paris, and a very enjoyable run it was, though my notes on the subject again seem rather scrappy. Those French lunches—very charming, but they always appear to have repercussions; it was fortunate the test run took place before, not after lunch, or there might not have been any notes at all.

(*To be continued*)

# International Standardisation of Rubber Test Methods*

THE seventh meeting of the Technical Committee ISO/TC 45 (Rubber) of the International Organisation for Standardisation was held at Zürich from September 30 to October 5, 1957 under its new chairman, Mr. J. M. Buist, who has succeeded Mr. S. A. Brazier in that office. The growth of interest in standardisation is reflected in the record attendance of seventy-seven delegates from fourteen countries representing France, Germany, India, Italy, Netherlands, Poland, Sweden, Switzerland, United Kingdom, U.S.A., U.S.S.R., Brazil, Czechoslovakia and Hungary, of which the last four were represented for the first time at ISO/TC 45.

## Work of ISO/TC 45 to Date

To obtain international agreement on methods of test is a relatively slow process, but the work done at previous meetings is now bearing fruit with the result that five ISO recommendations have been approved by council and are published (R 33, "Du Pont Constant Load Method of "Measuring Abrasion Resistance"; R 34, "Determination of Tear Strength Using a Crescent Test Piece"; R 35, "Determination of the Mechanical Stability of Latex"; R 36, "Determination of the Adhesion of Rubber to Textile Fabrics," and R 37, "Determination of Tensile Stress-Strain Properties"); nine draft ISO recommendations have been circulated to all member countries by ISO headquarters and the following subjects or test methods were considered sufficiently advanced for the secretariat to be instructed to issue them as draft ISO proposals:—"Tear Strength" (second draft proposal for the Delft test), "Compression Set," "Copper and Manganese in Raw Rubber and Latex" (second draft proposal), "Microhardness," "Density of Latex," "Volatile Fatty Acids in Latex," "Sampling of Raw Rubber," "Dirt in Raw Rubber," "Volatile Matter in Raw Rubber," "Ash in Raw Rubber," "Rubber Hydrocarbon in Raw Rubber," "Mooney Viscosity of Raw Rubber," "Mooney Rate of Cure of Raw Rubber," "Impact Brittleness Temperature of Elastomers," "Stiffness of Elastomers at Low Temperatures," "Volume Resistivity of Conductive and Anti-static Rubbers," "Ageing by Ozone Test," "Rubber-to-Metal Bonding," "Resistance to Liquids" (by swelling tests and effect on physical properties), "Terminology" (definitions), "Classification of Vulcanised Rubber" (coded specifications for rubbers graduated in series at various levels of physical properties for which ISO test methods already exist).

In addition, there was considerable discussion on subjects relating to the role of active and inactive copper in rubber; procedures for mixing, vulcanisation and evaluation of vulcanisates of raw natural rubber; procedures for hardness and compression set tests at low temperatures; determination of light ageing; tension testing of small test pieces.

## Present and Future Organisation

Hitherto much of the work of the Committee ISO/TC 45 has been conducted by working groups formed to study specific subjects. In general, this has been done by correspondence and the only meetings of the working groups (with one exception) have been those which preceded the plenary sessions. It was suggested by one delegation that greater progress could be achieved if the working groups could meet more frequently. Many delegations, however, felt this was impracticable owing to the difficulties of ensuring adequate representation. The U.K. secretariat undertook to study this question. However, there was a strong feeling at Zürich that working groups could be re-oriented by reducing their numbers and increasing their scope to cover a range of allied subjects. It was also decided that the chairmanship of the working groups should rotate at fixed intervals (probably four years) to enable different countries to play a greater part in organisation of the work. This will serve also to reduce the burden on the U.K. secretariat, which at present provides convenors for thirteen of the existing fifteen working groups. A new Working Group for Dynamic Testing was initiated at Zürich for which Germany has agreed to act as convenor.

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# Vibration: A Survey of Industrial Applications

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*In the forty-fourth Thomas Hawksley Lecture, delivered last Friday before the Institution of Mechanical Engineers, the author covered both forced vibrations and self-excited vibrations. We have chosen here to reprint the latter section of the lecture only. It covers vibration excited by dry friction, oil whip, leakage through narrow passages, flutter, stall phenomena, Kármán vortices, shimmy, instability of combustion in rocket engines, and a number of other cases, including instability in a boiling water nuclear reactor.*

## Vibration Excited by Dry Friction

A GENERAL class of vibrations exists in which the self-excitation is brought about by dry friction forces, which have the peculiarity of being greater at rest than in motion. Familiar examples are the screeching of unlubricated rubbing parts or the mechanism of a violin, which, indeed, requires the application of rosin on the bow to accentuate the difference between the friction forces at rest and in motion. The phenomenon was known and practically used for centuries before its scientific explanation, which, in Rayleigh's words (*Theory of Sound*, Vol. I, Section 138) is: "The sustaining power of the violin bow depends upon the fact that solid friction is less at moderate than at small velocities, so that when the part of the string acted upon is moving with the bow (not improbably at the same velocity), the mutual action is greater than when the string is moving in the opposite direction with a greater relative velocity. The accelerating effect in the first part of the motion is thus not entirely neutralised by the subsequent retardation, and an outstanding acceleration remains capable of maintaining the vibration in spite of other losses of energy."

This type of motion often is described as a "chatter" or a "stick-slip vibration," and although it occurs more often than it should, it will usually respond to a drop of oil, judiciously and timely applied. There is a case on record in which a rather large bascule bridge failed by structural fatigue as a result of vibrations occurring during the raising and lowering operations over a period of months, caused by a bearing from which the grease pot was spared for too long a time (Anon., 1929).* The only places where this type of disturbance assumes technical importance are where lubricants either are not wanted or are ineffective, some examples being (1) automobile clutches, (2) machine tools cutting into metal, and (3) outboard, rubber-lined, water-lubricated, shaft bearings.

In the first two of these, where the unfavourable friction characteristic is often unavoidable, the effects are kept within grounds by stiffening the construction, thus reducing the ratio between the exciting friction force and the elastic restoring force for a given amplitude of motion (Arnold, 1946; Hahn, 1953). Dampers in the form of inserts in the clamps of machine tools have been tried, and show some promise, but their practical merits at this time are doubtful. The water lubrication in the rubber-lined outboard bearings of ship's propeller shafts is reasonably effective at most service speeds, but does not work at extremely low speeds, which can result in a high-pitched squealing noise just after starting from standstill. This noise, broadcast through the water by the propeller blades was not appreciated during the war by the crews of submarines trying to get away undetected.

* References are listed in the original.

## Oil Whip

In a film-lubricated journal bearing, the angular direction of the load does not coincide with the direction of the minimum thickness of the oil film, as is shown by theory as well as by experimental observation. In normal operation, when the load on the usual horizontal bearing is the weight vertically downwards, this means that the point of minimum oil film thickness is found angularly ahead of the downward vertical in the direction of journal rotation by an angle somewhat less than 90 deg. Now consider a machine with a vertical shaft in which the journal bearings are guides only and normally carry no load, and imagine this machine to be whirling in a slightly bent state at its natural frequency. Then the geometry of the motion requires the thin spot of the oil film to rotate and be angularly in line with the rotating centrifugal force. The force of the oil film, then, however, is not in the direction of the centrifugal bearing load, so that no equilibrium exists, and the component of the bearing pressure force perpendicular to the centrifugal force or eccentricity tends to excite the whirl. For this mechanism a well-developed oil film is essential and this is brought about by the shaft rotation. If, in the absence of shaft rotation, an elastic whirl is initiated, no oil film is developed and the whirl is soon damped out. In general, for slow rotation and fast whirl the system is stable and, conversely, for fast rotation and slow whirl (that is, low natural frequency) the system is unstable and the whirl is maintained. Satisfactory experiments, supported by somewhat doubtful theories, place the neutral point (for a full 360 deg. bearing) at a running speed equal to about twice the critical speed, which means that a full 360 deg. vertical bearing rotating faster than twice its critical speed is inoperable. This rule is substantially correct for normal weight-loaded horizontal bearings as well, and the trouble increases in intensity with increasing speeds over and above twice the first critical. In the early days of the Parsons turbine for ships as well as for electric generation the rotors were made stiff, to run below the first critical; the transition to running speeds higher than critical came later and it was not until the early 1920s that the speeds reached twice the critical and the phenomenon of oil whip was discovered by Newkirk (Hagg, 1946). The generally accepted remedy is to relieve certain portions of the bearing by giving them substantial clearance, thus breaking up the 360 deg. circle into a number of shorter arcs, none of which individually should exceed 135 deg. Several theories have been proposed for this, which do not appear to be quite as convincing as the practical experimental evidence. Bearings of this type have been in continuous use in the steam turbine industry for thirty years with generally satisfactory results.

However, the trend towards still higher speeds (relative to the lowest whirling critical) is continuing and every year it becomes a little more difficult to get by with partial arcs only. For special experimental machines, running at 10,000 r.p.m., some firms now are using pivoted-pad bearings. The great invention of the tilted and pivoted-pad bearing, based on and inspired by the theories of Osborne Reynolds, was made at the turn of the century independently by Michell, of Australia, and Kingsbury, of the United States. These pads have been applied universally to thrust bearings, under the name of either one of the inventors, but their introduction on journal bearings, where the pads are segments of a cylinder instead of flat plates, has been sporadic and tardy. These pivoted pads are completely stable as far as oil whip is concerned, and it is quite possible that they will find more widespread application in high-speed machines, in spite of their unquestioned greater cost and complication.

Aircraft jet engines generally run well above twice their first critical, and the fact that they almost all use ball bearings instead of film-lubricated bearings is possibly explained by the fear of oil whip.

Recent very interesting experiments by Hull, soon to be presented to the Institution's sister society in New York (Hull, 1957), are shedding new light on this question.

## Leakage Through Narrow Passages

A group of self-excited phenomena has been observed in machines of which certain parts (sometimes large parts and sometimes small ones) vibrate at their natural frequency and by so doing periodically change the width of a narrow passage (for example, a labyrinth seal) through which a liquid or gas is flowing. The periodic changes in passage width cause velocity and pressure fluctuations of the fluid, which, when integrated over some area, cause periodic force variations on the vibrating machine part, obviously of the same frequency as the motion itself. When the phase relation is such that the excess pressure force on the vibrating part acts in the same direction as the vibratory velocity of that part, the fluid puts work into the vibration, which thus becomes self-excited.

A musical instrument based on this principle is the old-fashioned bellows-operated reed organ. The vibratory part there is the reed, being a thin steel cantilever about $\frac{1}{4}$in long and rather less than $\frac{1}{8}$in wide, which fits into a rectangular hole of the same size in a wall separating the bellows-fed pressure chamber from the open atmosphere. When the reed vibrates at its own natural frequency, it periodically varies the width of the passage; the air issues in puffs and the consequent pressure variations push the reed more in the direction of its own instantaneous velocity than against it, thus keeping it vibrating. The details of the flow and of the pressure variation are difficult to follow by theory.

In steam as well as in hydraulic turbines the fluid flows from a non-rotating, high-pressure vessel into a non-rotating, low-pressure vessel. Practially all of the fluid does that passing through the vanes or blades of the intervening rotating element, as intended, but since the rotating element cannot be attached to the stationary parts, and must have some clearance from it, inevitably a small fraction of the working fluid leaks through these small clearance passages from

the high-pressure to the low-pressure region. In order to keep this leakage small the passages are made as narrow as possible and often tortuous and complicated as well; they are then called labyrinth seals. If the rotor vibrates or whirls relative to the housing, these passages vary in width, and because they are so narrow in the first place even a very small vibration may cause considerable percentage variation in width with consequent large percentage variations in leak velocity and pressure. To follow the details of all this by theory and to come out with the right phase angle is easier when the answer is known in advance than when it is not. In practice, when such a case occurs and is properly diagnosed, we know that the phase angle is wrong and that changes in the geometry of the labyrinth seal will affect the phase, so that a practical cure of the trouble is not particularly difficult. On the other hand, we are not at present able to predict by theory whether a given design will be stable or not. Cases of this type are not common in turbines; in thirty years I have come across only three—a whirling steam turbine, a whirling vertical shaft water turbine, and a longitudinally vibrating horizontal steam turbine where the rotor was moving along its own centre line against the elasticity of the thrust bearing support structure. All three cases had natural frequencies of the order of 15 c/s to 50 c/s.

Recently another case was observed in a Ljungstrom type heat exchanger, which is a device for transferring heat from the stack gas to the atmospheric air prior to its entry into the combustion chamber of the boiler in a large steam-electric generating plant. The unit contains a rotor of some 30ft diameter and 15ft height, rotating about a vertical axis at approximately 1 r.p.m. The stack gas and the fresh air flow vertically through nests of vertical tubes in this rotor and the pressure differences are measured in inches of water. The rotating part is enclosed in a non-rotating housing so that some form of seal between the two is necessary to limit by-pass leakage of the stack gas as well as of the air through the annular space between the rotor and the housing. The rotor, suspended from a thrust bearing at the top, was found to sway sideways at its natural frequency of about 1 c/s. The consequent leakage passage width variations caused a pressure variation in the annular space (180 deg. stack gas, 180 deg. fresh air, separated by a baffle) of the order of a fraction of an inch of water only, but this very small pressure difference acting on an area of 30 by 15 square feet amounted to a considerable force. Again here there are many hundreds of these exchangers in operation, all apparently identical, and in only a few of them did this trouble appear, all others being satisfactorily stable.

The valves of diesel fuel-injection systems have exhibited this type of vibration. When injection begins, the fuel pressure pushes the valve off its seat, and while the fuel charge is rushing by, the valve floats on its seating spring. If it vibrates (at its high natural frequency, because the seating spring is stiff) it varies the width of the fuel passage and as a consequence, it may become unstable. Since no reports have been heard of trouble with these valves for some years, it is assumed that the instability has been successfully eliminated.

Just after the 1939–45 war there was a short period of great enthusiasm and active development in the field of "ultrasonics," a name coined for the region of frequencies in excess of 10,000 c/s, by means of which it was proposed to homogenise milk, kill bacteria, produce emulsions, and do many other things. For this it was necessary to make ultrasonic vibration generators, which could put out high energies, and at least one such generator was built on the principle just described.

## Flutter

Flutter (Garrick, 1957) is the self-excited vibration of a structure (usually, but not necessarily, a part of an aeroplane) in a fluid flow where the energy source is the flowing fluid (usually air). The first cases that were observed, diagnosed and explained occurred early in the development of the aeroplane, in the wood-canvas-and-wire days. They were named "aileron flutter" and consisted of an up and down bending vibration of the wing associated with a periodic rotation of the aileron about its pivot axis. Since the aileron's centre of gravity was not lcoated in the pivot axis, a vertical vibration of that axis caused an angular flapping of the aileron, which, in turn, led to a periodic change in the effective angle of attack of the wing with a consequent lift variation. If the phase between these variables was such that a maximum of lift occurred at the instant of maximum upward vibrational velocity of the wing, the air stream pumped work into the motion and made it unstable or self-excited. After some years of trial and error an effective remedy for this trouble was found, in the early 1920s, by "balancing" the aileron. This consisted of shifting some of its area and mass ahead of the pivot axis, thus placing the centre of gravity in that axis, or, even better, by making the pivot axis a "principal axis of inertia" of the aileron. It was assumed that this disposed of the problem, but a few years ago it reappeared with transonic aeroplanes, where it is referred to as "burr"; there it is associated with shock waves, and it is altogether a much more complicated phenomenon than the old-fashioned low-speed aileron flutter.

Another type of flutter which was also observed quite early consisted of a combined vertical bending and torsional motion of the entire wing in which the aileron did not take part. This was, and is, called "classical wing flutter" (as opposed to "stall flutter" to be discussed in the next section), and its explanation did not appear until 1935 by Theodorsen (1935). Whereas the old aileron flutter usually occurred at such a low frequency that the aerodynamic forces on the wing were determined by the instantaneous value of the angle of attack of the wing and aileron (yielding to a theory of a "succession of steady states"), this was no longer true for classical wing flutter. Theodorsen derived expressions for the value of the sinusoidally varying lift force and moment on the wing caused by a sinusoidal variation of the angle of attack and of the vertical position of the wing. These expressions were complicated, containing the wind velocity $V$ and the frequency $\omega$ in an intricate non-linear way. Assuming an undamped harmonic motion of the wing under the influence of this lift force and moment led to a pair of complicated algebraic equations in the two unknowns $V$ and $\omega$. The solution for these gave the flutter speed and the flutter frequency. The speed was such that below it a wing vibration would decrease in time, being damped; above it the vibration would grow, and at the flutter speed, by definition, the vibration would remain at constant amplitude undamped.

The frequency of the flutter motion was found to be quite different from the natural frequency of the wing in still air, which places the flutter problem in a class by itself among self-excited vibrations. This is because the natural frequency is determined by a balance between spring and inertia forces and in most practical self-excited cases the exciting force is small with respect to the spring and inertia forces. In a fluttering wing, however, the exciting alternating wind force is of the same order of magnitude as the spring or inertia force and hence affects the frequency.

With this theory the critical flutter speed could be roughly calculated for each wing, and the result depended on several parameters, such as the size, the mass and rotatory inertia, the bending stiffness and the torsional stiffness. After some experience it was found that among these variables the torsional stiffness was by far the most important one, so that in general the flutter speed could be raised by increasing the torsional stiffness of the wing structure. By this time canvas and wood had given way to aluminium wing structures of considerable thickness and the flutter situation was under adequate control in the period just preceding the 1939–45 war.

Flutter was not limited to the wings alone; it appeared as well in the rudder, elevators and tail surfaces and also in the propeller blades: in short, wherever some aerodynamic surface felt a change in its wind force as a result of its own vibratory motion. Once the phenomenon was well understood for a wing, flutter in other configurations could be explained when it appeared and eliminated by stiffening or other means. Then, during the war and in the period thereafter, the development of the aeroplane became explosive: in entering the subsonic and supersonic domains it became necessary for aerodynamic reasons to reduce the thickness of the wing sections, thus drastically decreasing the torsional stiffness. Also, the expressions for the harmonic lift force and moment caused by the vibration are entirely different from those for the subsonic case and, what is more serious, these expressions are not yet known theoretically. Thus, before a flutter calculation can be attempted the forces as a function of the frequency have first to be determined by wind tunnel tests. Whereas in the simpler pre-war aeroplanes an idealisation of the wing into a "beam" was reasonably adequate, in the new types this is no longer justified and the frequencies have to be calculated on the basis of an idealisation in terms of a "plate." These calculations (for which electronic computers are becoming more and more indispensable) are so intricate that the flutter problem has grown into a recognised science by itself with a name of its own, "aeroelasticity," with an extensive body of literature (Bisplinghoff, Ashley, and Halfman, 1955; Bisplinghoff, 1956), and a large and growing group of specialised engineers.

Whereas the usual method of determining the flutter speed of a proposed design is by calculation on the basis of aerodynamic coefficients found by wind tunnel testing, it is also possible to do it entirely by model test. If a reduced scale model of the aeroplane, or of a representative portion of it, be built of the same materials and placed in a wind stream, then the flutter speed of the model is the same as that of the full-scale aeroplane and the flutter frequency of the model is faster than that of the aeroplane in the size ratio. The dimensionless combination $fc/V$ (where $f$ is the frequency, $c$ the "chord" or width of the wing, and $V$ the flutter speed) preserves its value unchanged, and it can be recognised that it is equal to the number of full vibration cycles during the time it takes the wind to progress one wing chord $c$. This quantity (sometimes appearing in the literature with a factor $\pi$) is known as the "dimensionless frequency." The recent trend towards thinner and torsionally more flexible wings is expressed by the fact that the dimen-

sionless torsional frequency $f_\theta c/V$ for fighter aeroplanes has been reduced by a factor of between 3 and 5 during the last fifteen years (Bisplinghoff, 1956). Model testing for flutter is not generally practised on account of the very real difficulties in producing true geometric reduction in size. If such a model is to be made at a scale of 1/20, it is theoretically necessary to reduce the skin to a thickness of 1/20 and to attach that skin to the spars with rivets of 1/20 size, and when the practical difficulties force us to a simpler " equivalent " construction, we can never be quite sure whether or not the modifications have affected the stiffness, and, hence, the flutter speed.

So far all authenticated cases of classical flutter have been in aeroplanes or missiles. In 1940 the Tacoma suspension bridge failed by wind-induced vibrations and for several years thereafter one of the possible explanations for the failure was in terms of flutter, which, however, was disproved by special wind-tunnel experiments (Farquharson and others, 1949–54) in the period 1945–50.

Another phenomenon that has been with us for some fifty years is the " singing " of ship propellers or of the rotors of water turbines, which is a vibration of a frequency of the order of 500 c/s of small amplitude, manifesting itself by a loud penetrating noise, but seldom leading to structural failures. Obviously it is some sort of self-excited motion in one of the higher modes of the propeller blades caused by the water stream. Many papers have been written on it with various explanations (Shannon and Arnold, 1939), but no general agreement exists among the workers in the field on the exact mechanism of the phenomenon. A satisfactory practical cure has been found in sharpening the leading as well as the trailing edge of the blade.

Recently a case appeared of a destroyer vibrating at its natural frequency of some 300 cycles per minute, as a beam in a horizontal plane (so-called lateral vibration) in a three-noded mode. It did this only at high speed through the water, the vibration disappearing below 80 per cent of the top speed. An explanation in terms of classical flutter of the entire hull was put forward but proven wrong by the discovery that the instability could be made to disappear by changing the length of the coupling rod between the two rudders. These rudders moved in unison, and the change in the rod length increased the relative angle between the two rudders by a few degrees. No precise detailed explanation is available ; it may have been closely related to a classical aileron flutter, it may have been caused by a stalled condition of the flow near the rudders, or possibly by some other mechanism not diagnosed as yet.

## Stall Phenomena

An aerofoil section, be it an aeroplane wing or a turbine blade, operating in a normal fashion with a sufficiently small angle of attack, experiences a lift force nearly proportional to the angle of attack. Imagine such a section mounted cantileverwise and vibrating at its lowest natural frequency in the fluid stream by bending in its limber plane. During the down beat of its motion it feels a small wind coming from below, which, compounded with the main wind stream, causes an apparent angle of attack somewhat greater than the no-vibration angle and, consequently, the section experiences a lift greater than normal. Similarly, during the upbeat of the vibration the lift is smaller than normal. Thus the excess part of the lift is always a force opposite in direction to the vibrating velocity of the section, which means that the motion is damped and the system is said to be dynamically stable. However, when the average no-vibration angle of attack surpasses some critical value of about 10 deg. the flow breaks loose from the aerofoil which is then said to be stalled, and in that condition the slope of the lift versus angle curve is the reverse from the previous case ; that is, for an increased angle of attack the lift decreases. With this change in sign in the foregoing argument its conclusion is reversed, so that a vibrating aerofoil section in the stalled condition is dynamically unstable : the excess lift force caused by the vibration is always in the same direction as the velocity. Hence a stalled blade will vibrate by itself and this phenomenon is called " stall flutter." In aeroplane wings it is not of particular importance, because when stall occurs, the craft loses its lift as well as its control so that the pilot has more serious worries than just a little flutter.

In aeroplane propellers with fixed blades during take-off (low speed of the aeroplane with fast rotation of the propeller) the angle of attack is large and certain parts of the blade become stalled. However, the damping provided simultaneously by the normally operating parts of the blade keeps the vibration from developing and the problem was never of great practical significance.

However, with the advent of jet aircraft propulsion the stall problem in the blades of the axial compressor has become very serious indeed, and it is still very much with us at present. The starting point in the design of a compressor is the ratio between the rotor peripheral speed and the axial entrance speed of the air, and on the basis of this ratio all blades in the various stages can be designed with proper angles of attack for perfect operation. But during the take-off, and in certain other essential operating conditions, the ratio between these two speeds is necessarily different and hence the angles of attack are modified. Thus the design must be made as a compromise between the various operating conditions, and we are forced to accept situations where some rows of blades operate close to the stall angle while others do little work, having a very small angle of attack. Such a compromise design can easily be carried out satisfactorily for compressors of moderately small compression ratios of, say, 3 : 1. For increasing compression ratios it becomes more difficult and finally impossible.

At least two methods of designing around this difficulty have been devised and have been incorporated in current engines. The first and most drastic of these is to cut the axial compressor in two parts, running it on two shafts (one passing through the bore of the other), each of which finds its own appropriate revolutions per minute, depending on the operating condition. This is called a " double spool engine " and with it the problem of a compressor of a ratio 9 : 1, which it would be impossible to design properly on one shaft, is reduced to that of two compressors of ratios 3 : 1 each. The second method is to modify the angle of the stream entering each row of rotating blades by making the non-rotating guide vanes angularly adjustable.

When in operation a row of blades actually reaches the critical stall angle, violent stall flutter is inevitable, and the blades will surely fail by bending fatigue, which makes the avoidance of this condition a complete necessity. But when the overall angle of attack on a row of blades is somewhat smaller than this " critical angle for fully developed stall," something less serious happens which is known as " rotating stall." The passages between two, three, or four adjacent blades go into a stalled condition and this block of stalled passages moves relative to the stator in the direction of the rotation with roughly half the speed of that rotation (and hence relative to the rotor, it moves at half speed in a direction opposite to that of the rotation). Sometimes one such block exists, sometimes two or even three, all moving separately with respect to the rotor at the same speed ; the passages between these blocks having smooth flow without stall. A tentative sketchy explanation (Fig. 1) is that the flow resistance in a stalled passage is greater than in a smooth one, the stalled air acting like a partial plug. Then the approaching air tends to flow around the obstacle, which in the passage *A* tends to increase the angle of attack and in *B* tends to decrease it. Thus, the passage *A* will stall next and *B* tends to become smooth if it were stalled previously. Hence the " plug " will move in the direction opposite to that of the rotation relative to the rotor, but so far the explanations of why that should happen at roughly half the speed of rotation have not been entirely satisfactory (Stenning, Kriebel and Montgomery, 1956). Research on the subject is going on in various places at this time.

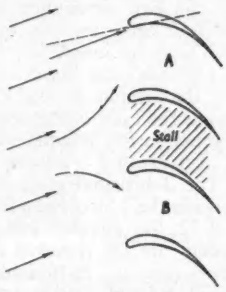



**Fig. 1—Explanation of the mechanism of rotating stall in the compressor of an aviation jet engine**

An individual blade in a case of rotating stall (Fig. 1) will be alternately stalled and smooth in a reasonably rapid succession. Such instability as the stall itself might cause will not persist long enough in time to build the vibration up to a large amplitude, and during the subsequent period of smooth flow the motion will be damped out again. Thus, the probability of structural failure from the stall instability itself is not great. However, when an individual blade is suddenly enveloped by the stall it experiences an impulse, and since the plug or plugs of stalled air move relative to the blades at almost constant speed, each blade is subjected to periodically recurring impulses, which if their frequency is close to a natural one may cause failure by resonance. Since the number of plugs and their relative angular location cannot as yet be predicted, the condition of rotating stall should be avoided if at all possible. This imposes a severe handicap on the designer, so that at the present time the phenomenon of rotating stall sets a limit to the compression ratio that can be built into a single-shaft axial compressor.

For the past thirty or more years large high-voltage electric-transmission lines under certain climatic and wind conditions have been plagued sporadically with a vibration known as " galloping," which has been partially explained as a stall flutter (Cheers, 1950). It appears once a year or so in Canada and in the northern United States, when the lines are sleet-coated and a wind of at least 15 miles per hour is blowing perpendicularly to the line. The cross-section of a sleet-coated wire may take various forms, none resembling true aerofoils, but some of these shapes will show a greater lift or vertical force from the wind when the angle of attack is diminished. Thus, a stall instability may occur. The result is a vertical vibration of the entire span

at a slow frequency of about 1 c/s and a large amplitude of up to 10ft at midspan. In all these years no simple practical cure has been found, except the questionable one of melting off the sleet by partially short circuiting the lines. The explanation in terms of a stall flutter associated with purely up and down motions is probably too simple, because torsional motions of the wires have often been observed to accompany the more spectacular vertical ones. The National Research Council of Canada in co-operation with the electric power companies of Ontario and of some of the adjacent American states continue research on this subject.

### Kármán Vortices

When a cylinder, not necessarily of circular cross-section, is placed in a stream flowing perpendicularly to its axis, vortices are formed which break away from the cylinder alternately from the two sides, causing an oscillating force in a direction perpendicular to the stream velocity and also perpendicular to the cylinder axis. There are good drawings of these eddies in Leonardo da Vinci's notebooks, but the first description in modern terms came four centuries later by Strouhal (Rayleigh's *Theory of Sound*, Vol. II, Section 372), who expressed the frequency of eddy shedding by the formula $f=0{\cdot}22V/D$, which means that one full cycle of the sidewise force variation occurs during the time that the flow progresses $1/0{\cdot}22=4{\cdot}5$ diameters of the cylinder. The dimensionless quantity $fD/V$ is now known as the " Strouhal number " ; it is about 0·22 for circular cylinders and assumes values not far removed from 0·22 for other cross-sections. In 1911 von Kármán (Kármán and Rubach, 1912) published a paper on these vortices explaining them in so much more detail than had been done previously that they have been named after him ever since. During the past thirty years this phenomenon has given much trouble on various structures and has been responsible for the total destruction of a major engineering work—the Tacoma bridge. In ordinary circumstances the alternating force from the eddies is of no particular interest ; only when the Strouhal frequency happens to coincide with a natural frequency of the structure on which the stream acts, and resonance takes place, does the phenomenon assume engineering importance. This has occurred on electric transmission lines, submarine periscopes, smoke stacks, a roofless oil storage tank and . . . the Tacoma bridge.

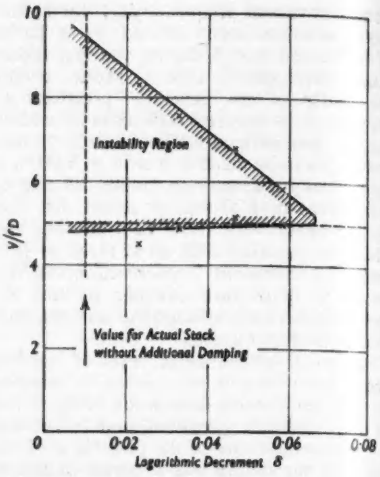
In a transmission line of $D=2$in diameter and a wind speed of 20 miles per hour or 30ft per second, the Strouhal frequency comes to approximately 40 c/s, which corresponds to a high mode of natural vibration of the line showing a configuration of many (say, twenty) sine waves along a single span. In this mode the line vibrates at an amplitude of a fraction of an inch, resulting in frequent bending fatigue failures. A good practical remedy exists in the form of inertial friction dampers which are mounted on the line at some 6ft distance from the point of attachment to the towers. It will be appreciated that this motion of the transmission line is fundamentally different from the " galloping " motion caused by stall flutter, discussed previously.

During the 1939–45 war annoyance was experienced by submarine captains, because during a sneak-approach to a target at a speed of some 5 knots, the eddies in the water acting on the extended periscope tube (of about 8in diameter) with a frequency of 2 c/s or 3 c/s came to resonance with the natural cantilever frequency of the periscope and the resulting sidewise vibrations blurred the target picture. One method of eliminating the trouble would be to increase the tube diameter, which by bringing the Strouhal frequency down and the natural frequency up would push up the critical speed out of the operating range.

Smoke stacks will sway sidewise in a steady wind of the proper critical speed if their internal damping is sufficiently small. Brick or concrete chimneys have never exhibited this vibration as far as we know, but welded steel stacks are all prone to it. In the very large ones the situation has now reached the danger point ; a few years ago a welded stack of 16ft diameter and 300ft height, vibrating in a 50-knot wind at a frequency of about 1 c/s, actually failed by local buckling and cracking. Stacks of this size are not safe without some provision for increased damping, either by lining them with concrete inside or by the use of friction dampers in guy wires.

The expression $0{\cdot}22V/D$ for the Strouhal frequency applies to circular cylinders that do not vibrate. When a chimney vibrates by resonance, its elastic and inertia forces are many times greater than the Kármán wind force, so that the frequency at which it can vibrate is its natural frequency only. It had been suspected for many years that if a cylinder vibrated at a frequency somewhat different from the natural Strouhal frequency of the eddies, the eddies could be forced by the cylinder motion to take place at the cylinder frequency, and thus still excite the cylinder even at a frequency different from Strouhal's. This vague belief was cleared up recently by experiments of C. Scruton at the National Physical Laboratory (Scruton, 1955), which shows that for very small damping a chimney could be excited at frequencies up to twice the Strouhal frequency. This means that a stack may be in trouble in a range of wind speeds extending between the calculated Strouhal critical speed and twice that value. The results of that investigation are shown in Fig. 3.

The most spectacular case of a vibration caused by Kármán vortices occurred in 1940 on a suspension bridge in Tacoma, Washington, in the Pacific Northwest of the United States. The cross-section of the bridge was a




Reproduced from Scrutton (1955). The ordinate $V/fD$ is the reciprocal of the Strouhal number and the abscissa is the "logarithmic decrement" or percentage decay in amplitude per cycle of the stack in still air.

**Fig. 3—Stability diagram of a circular steel smoke stack in the wind, obtained by a model test in the National Physical Laboratory**

horizontal " I " of 39ft width with two 8ft high vertical flanges of solid steel. Under a side wind of 42 miles per hour, the bridge became unstable torsionally, vibrating with angles up to ±45 deg. at the quarter and three-quarter span points with torsional nodes at midspan and at the two ends, resulting in a complete structural failure. For several years after the event, the exact mechanism of the cause remained unknown until by a series of wind-tunnel model experiments it was shown to be due to Kármán vortices coming off the sharp top and bottom edges of the vertical flange facing the wind (Farquharson and others, 1949–54). In the newly reconstructed bridge three changes were made :

(1) The solid vertical flanges were replaced by open trusses through which the wind could blow freely.

(2) Longitudinal slits were provided in the horizontal bridge deck between traffic lanes, preventing the possibility of pressure differences between top and bottom at those points.

(3) The " open " I-section was replaced by a " closed " rectangular box section (with three of the four sides being open trusses) which torsionally is a hundred times as stiff, thus raising the torsional natural frequency well above the Kármán frequency at any conceivable wind speed.

This last remedy was subsequently applied to the San Francisco Golden Gate Bridge and to some other bridges which had shown very mild tendencies towards wind vibration. In this connection it may be of interest to remember that about a century ago Stephenson proposed a suspension bridge with a box girder, and that in the final design Fairbairn preserved only the box and eliminated the

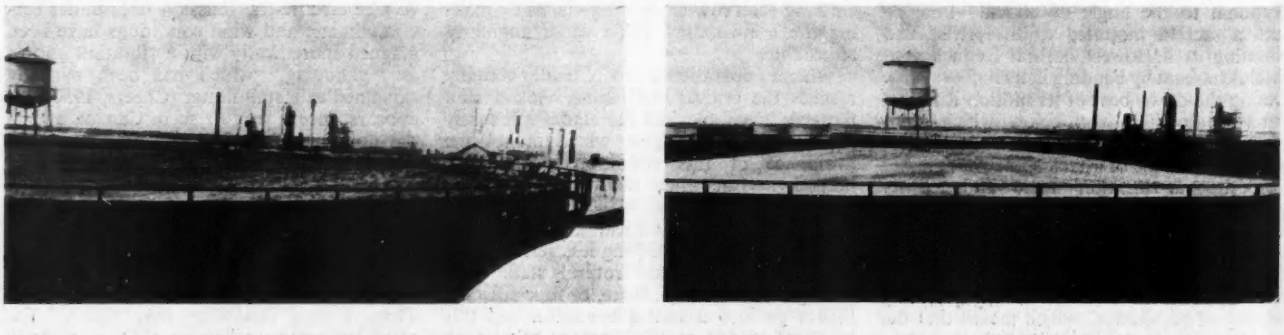


**Fig. 2—Two pictures (taken some seconds apart) of an oil storage tank filled with sea water, showing a standing wave, probably caused by Kármán vortices**

suspension feature (Anon., 1875). In the course of the next 100 years, bridges were gradually made longer, lighter, and more flexible, until suddenly the new limitation of the Kármán vortices was met, which reintroduced the box structure and put a stop to the trend towards greater flexibility.

The most recent example of a Kármán effect, observed in 1954, is of no great technical importance, but it is believed to involve the largest vortices encountered so far. Fig. 3 shows a newly constructed, as yet roofless, cylindrical oil-storage tank of 150ft diameter and 48ft height, which when almost filled with sea water for an acceptance test, exhibited a standing wave of 8ft peak to peak amplitude in a steady wind of 30 miles per hour. Although no vortex could be seen in the free atmosphere, the other observations fit the Strouhal relation quite well, so that in all probability we are dealing here with a vortex of some 100ft diameter.

### Shimmy

The Oxford dictionary asserts that "shimmy" is an American term, born in 1919, signifying a "kind of fox-trot accompanied by tremulous motions of the body." In a past static age our profession adopted into its technical vocabulary many words relating to the body, such as footings, knees, arms, ears, eyes and teeth, and it is fitting that in this new dynamic era the list should be augmented by an obviously dynamic word. The next edition of the dictionary might add another definition, such as "techn. (1925); an angular vibrating motion about a vertical axis of a wheel in a moving vehicle resulting in a sinusoidal path of the wheel on the ground."

This type of motion was first observed in the castored small wheels of hand push carts in factories, and did not receive any particular attention. Then, in the late 1920s, it appeared in the front wheels of automobiles, brought about at that time by a lowering of the air pressures in the new balloon tyres. The two front wheels were rotating on shaft stubs integral with a common front axle, on which the car body was elastically supported. If on an uneven road one wheel would go up, passing over an obstacle, the front axle would tilt and the two front wheels would rotate through a small angle about a fore-and-aft axis along the centre line of the car (a "rolling" motion). Since at running speed the wheels act as gyroscopic bodies, such an angular vibration about a fore-and-aft axis is gyroscopically coupled to a vibration about a vertical axis, which is a shimmy motion. This was a nuisance for a number of years, and it was attacked by the introduction of dampers, retaining the basic geometrical construction, until a fundamental cure was found in mounting the two front wheels independently, each on a parallelogram linkage so that the up and down motion of the wheel could take place in its own plane without rolling rotation. This destroyed the coupling between the up and down motion and the angular shimmy motion and constituted a complete remedy of the trouble. At the time, during the early 'thirties, an extensive literature appeared on the subject, particularly in the automotive journals, which is now of historic interest only.

During the 1939–45 war trouble was experienced in the castored tail wheels of aircraft landing gears by the Germans and the Allies alike, both sides of the conflict working hard on it and producing many reports which were kept secret from the enemy and consequently equally secret from almost everybody on the friendly side as well. The trouble could be eliminated on an empirical basis by torsional dampers or by changes in dimensions, and these practical cures were often accompanied by official reports covering the theory of highly simplified systems, which later proved to be non-representative of the truth. More recently, with the explosive increase in weights, sizes and landing speeds of aeroplanes, the trouble has reappeared in a very serious manner, this time in the swivelling nose wheel. Fig. 4 shows the last track

Fig. 4—The last track of a large aeroplane with a shimmying nose landing gear

made by a very large and heavy aeroplane, ending in a collapse of the front wheel and consequent wreck and destruction by fire of the entire ship. An idea of the violence of such an occurrence is obtained from the fact that the wheel of 4ft diameter shimmied through some 30 deg. on each side of neutral with a frequency of near 30 c/s.

An extensive theoretical and experimental analysis of this phenomenon by W. J. Moreland (1954) showed that simplifications in terms of two or three degrees of freedom failed to stand the test of experimental verification. In order to do justice to the problem it was necessary to consider four degrees of freedom in the landing gear alone, apart from the aeroplane of which it forms a part. These were: (1) the shimmy angle of the wheel; (2) the lateral or sidewise deflection of the vertical strut due to its elasticity; (3) the sidewise elastic deflection of the rubber tyre; and (4) the torsional angle of the dashpot or damper structure, which necessarily has to be made very light.

The result of the analysis has to be expressed in terms of a number of significant parameters, such as the landing speed, the castor distance or "trail," the radius of the wheel, the mass and moment of inertia of the wheel as well as of the strut and other parts, the constants of the dashpot and of the rubber tyre, the various structural stiffnesses and the weight load on the wheel. It was found that fifteen such parameters were needed to describe the important properties of various landing gears.

The calculation of such a complicated system by ordinary means is prohibitively time-consuming and becomes a practical possibility only with the help of electronic computers. Moreland and his associates during some years calculated several hundred systems on the computers. In addition, they constructed a versatile, small-scale model of a landing gear in which the various constants or parameters could be changed conveniently. The computed results when compared with the model tests showed satisfactory correlation. Even this is not the whole story because these results would describe the behaviour of the landing gear only when attached to an infinitely rigid and massive aeroplane, of which the point of attachment of the landing gear strut moves forward in a straight line, even in the presence of a violent shimmy at 30 c/s. No aeroplane frame is rigid at this frequency, and its lateral impedance (as a function of frequency) can be calculated for a new design or determined experimentally for an existing construction. The actual behaviour of a proposed landing gear on a given aeroplane can then be determined by matching the impedance of the aeroplane frame with that of the landing gear.

In this way it is now possible to predict the stability of a new design. The old empirical procedure had broken down, because for certain conditions roughly described as wheels of large diameter and inertia, it was proved impossible to eliminate the instability by torsional damping alone, so that no matter what was done in the way of damping, shimmy would occur. Cases of this type can be made to behave satisfactorily only by a proper design of several other parameters, such as size, mass and stiffness.

A phenomenon closely related to shimmy is the "nosing" of locomotives or other railway carriages on their tracks, in which the vehicle sways sideways, sometimes quite violently, at a frequency of about 1 c/s or slower (Langer, 1938). This problem was of great practical importance in the period from 1910 to 1935, but now it seems to have been solved satisfactorily by proper design.

### Instability of Combustion in Rocket Engines

A rocket is a device consisting of a combustion chamber and a nozzle through which the combustion products are expelled rearward at high velocity. They are being made with solid or liquid propellants; in the solid propellant type the fuel and oxidiser are premixed, as in gunpowder, into a solid block, which is made to burn on one face; in the liquid propellant type the fuel (for example, gasolene) and the oxidiser (for example, liquid oxygen) are carried in separate tanks and are pumped to the combustion chamber where they are mixed and burned together. The solid propellant rocket is very ancient and has been popular for a thousand years in Chinese New Year celebrations; the liquid propellant type is newer, having been introduced to modern civilisation under the sinister name V2.

It has been known for many centuries that Chinese toy rockets can be made to scream loudly at a high pitch, and this effect under the name of "pyrotechnic whistle" has been used in war, sometimes psychologically to frighten the enemy, and also as a decoy for acoustically homing underwater torpedoes. In a screaming rocket or pyrotechnic whistle

the combustion is not smooth but has fast alternations in intensity which are accompanied by fluctuations in pressure in the combustion chamber. If the rate of combustion is a function of ambient pressure, a fluctuating pressure causes a fluctuating combustion and consequent gas production, and hence a fluctuating pressure again. This is a typical feedback mechanism, which becomes unstable if certain phase relations occur.

About a century ago illuminating gas was one of the new wonders of engineering ; it was used in open jets, of which the combustion under certain circumstances was found to be unstable. These " singing flames " were made quite fashionable in London society by marvellously spectacular demonstrations and lectures in the Royal Institution by its Professor John Tyndall (Tyndall, 1883). Some years later Rayleigh wrote his great book and commented as follows (" Theory of Sound," Vol. 2, Section 322g) : " If heat be periodically communicated to and abstracted from, a mass of air vibrating, for example, in a cylinder bounded by a piston, the effect produced will depend upon the phase of the vibration at which the transfer of heat takes place. If heat be given to the air at the moment of greatest condensation, or be taken from it at the moment of greatest rarefaction, the vibration is encouraged." This was meant by Raleigh to apply to Tyndall's singing flames. Not many years thereafter, however, the heat so communicated and so abstracted in a " cylinder with a piston " was indeed " encouraging the vibration " of the pistons of diesel engines to propel ships across the oceans of the world.

With the recent development of rocket engines, particularly with those of very large size and thrust, this instability has come to us as a very serious technical problem (Ross and Datner, 1954). The phenomenon starts suddenly without warning ; the pressure fluctuations in the combustion chamber may be as high as $\pm 100$ per cent of the mean pressure, the frequency as high as several thousand cycles per second, and often it is all over in a fraction of a second with the machine to pieces. It is not healthy to be near a large rocket when it is operating, so that all observations have to be made by instrument at a safe distance, and obviously it is not easy to contrive high-frequency sensitive pressure pick-ups in the interior of a flame, so that experimental research into this problem is fraught with extraordinary difficulties.

The first appearance of this trouble in the United States occurred immediately after the termination of the war in 1945, on a liquid propellant rocket engine. It was of a relatively low frequency, about 100 c/s, of relatively low intensity, the pressure variation being about $\pm 25$ per cent of the mean, and hence not destructive. Adequate measurements could be made, showing that the pressure variations extended into the feed lines of the fuel as well as of the oxidiser. It was reasoned that at the moment of high pressure in the combustion chamber the inflow of fuel and oxidiser was impeded. If then at this instant of high pressure there would be less fuel supply and less combustion and consequently less heat generation, the phase angle of Rayleigh's rule would be just wrong, and the system would be completely stable. However, the combustion itself takes time, and the flow of the liquids through the pipe system also takes some time, so that the instant of minimum heat generation lags behind the instant of maximum pressure by some (short) time. Rayleigh now states that if this time lag lies between 1/4 and 3/4 period of the fluctuation (or between 5/4 and 7/4, 9/4 and 11/4, &c.) the phenomenon is unstable. This is a reasonable explanation of the observed instability, and for sufficiently slow frequencies the time lag can be calculated after a fashion. At very slow frequencies of the order of 1–10 c/s this effect has been observed in boilers or industrial oil-fired furnaces when the air supply to the burner is choked, and a good practical remedy then is to admit some extra air into the furnace, by-passing the burner blower. Similarly the observed instability of rocket engines (in the " low frequency " range of 40–200 c/s) can be remedied in practice by making changes in the supply lines, pumps or nozzles and hence, although the real fine points of the theory are not completely understood, the situation is acceptable.

However, with the high-frequency type of rocket engine instability (from 800 c/s up), there is at present no such practical cure available. Experiments have shown that in these instances the pressure fluctuations are practically limited to the combustion chamber itself and hardly penetrate into the feed system. Here, then, we have a combustible mixture of gas (which is kept permanently combustible by the inflow of fresh gas and the outflow of burnt gas) which can vibrate in any one of the many possible natural modes of vibration of a gas in some sort of chamber. If the rate of combustion of the gas would reach a maximum at the same instant as the pressure (as seems natural to assume), then we have satisfied Rayleigh's rule or in other words we have the situation in a diesel cylinder or in a gas turbine cycle and, consequently, work is done on the vibratory cycle which will then continue for the same reason that a diesel engine or a gas turbine keeps on running. If this were the case, then all possible modes of motion of the gas in the combustion chamber would be unstable and no rocket engine could run smoothly. Evidently this is not the case and there must be a time lag between the maximum pressure and the maximum combustion. For stability this time lag must be at least 1/4 period, or $1/8 \times 10^{-3}$sec in a 2000 c/s vibration. The detailed precalculation of this is not possible at this time on account of the many unknowns in the combustion process. Vigorous researches on the fundamentals of combustion are now being pursued in most countries, and in this connection it may be of interest to quote another sentence from Rayleigh (Vol. 2, Section 322h) : " Partly in consequence of the peculiar and ill understood behaviour of flames, the thorough explanation of the phenomena now under consideration is a matter of some difficulty."

## Various Other Cases

In conclusion a number of cases of a miscellaneous nature that have been of recent interest will be briefly mentioned.

The field of ultrasonics (Bergman, 1954) consists of the applications of frequencies above the audible range (above 10,000 c/s), which are usually and most conveniently generated by electronic techniques. Its development started with underwater signalling devices during the 1914–18 war, remained more or less stagnant during the 'twenties and 'thirties and received a vigorous boost again during the 1939–45 war with the creation of " Sonar " and similar techniques. An unexpected by-product of this work was the explanation of the old question of the flying of bats in the dark as an ultrasonic sonar-echo mechanism. The experience gained during the war has led to some peacetime applications, principally in measuring techniques.

Ultrasonic waves are now being used for detecting cracks or flaws in metal structures, particularly in welded joints, by moving a noise generator over the surface from point to point (Bergman, 1954). When this instrument passes over a sudden change in thickness of the steel plate or structure, or when it passes over an interior crack or non-metallic inclusion, there is an indication on a meter. The use of this method of inspection is increasing, and it is becoming a serious competitor to the older and more familiar X-ray technique.

The measurement of the violent and rapid temperature changes in a cylinder of an internal combustion engine during the small fraction of a section immediately after the spark ignites the gas is obviously a difficult problem. It was accomplished recently (Livengood, Rona and Baruch, 1954) by sending an ultrasonic wave across the cylinder and measuring the time taken between the start of the signal and the return of the echo from the opposite cylinder wall, thus determining the velocity of sound in the gas, and by direct correlation, its temperature.

In systems involving a servo-mechanism small changes in the value of the quantity to be controlled or kept constant result in operations by the servo-motor with considerable power and this reacts directly on the variable to be controlled. Thus if certain unfortunate phase relations occur, the system may become unstable. Consider, for example, the automatic steering mechanism of a ship or aeroplane. A gyroscopic direction sensor is mounted in the vehicle and when this sensor finds a small deviation between the actual direction of the ship and the desired direction, it causes power to be applied to the servo-motor controlling the rudder. Now imagine the vehicle to be vibrating in one of its natural bending modes and let the gyro-sensor be mounted in such a location that it experiences a vibrating angular motion. Then the rudder will receive vibrating impulses at the same frequency and the phenomenon may become unstable. In principle this may occur at any one of the natural modes of the system, even the higher ones with fast frequencies. In an ocean ship this possibility is quite excluded because the steering engine, be it steam or electrically operated, is far too slow, and under the influence of a rapid alternating signal the rudder would simply stand still in the neutral position. Also the angular amplitude of motion to be expected in a ship at the location of the gyro-sensor should be extremely small. In an automatic pilot of an aeroplane the possibility of such an instability is less remote, and when the system is made more flexible yet and is required to respond to fast signals as in some guided missiles, the possible appearance of self-excited vibrations of this type must be considered seriously during the design stage.

Our most modern power plants actually operating involve nuclear fission reactors, and although there are indications that this type of plant may become obsolete before it has properly grown up (in favour of some sort of fusion process), we will assume that nuclear fission reactors will remain of interest to mechanical engineers for some time to come. Several types of this reactor are being developed (Cockcroft, 1957), one of which is the boiling water reactor. The water acts as a " moderator," which means that the fissionable material will react and generate heat only when it is surrounded by water, and in the absence of water the reaction dies out immediately. In a properly operating boiling water reactor the radioactive material is surrounded by water with a uniform distri-

bution of small steam bubbles. Suppose now that the reactor momentarily acts at greater than normal intensity. Then it will rapidly boil the surrounding water, and soon it will find itself in an atmosphere of steam, with the result that the reaction stops and no more heat is generated. The steam rises up and water rushes back in its place, thus re-igniting the atomic fuel, and so on. Instabilities of this type have been observed and they are of an intensity awesome to a person accustomed to ordinary mechanical vibrations. The maximum rate of power generation (in kilowatts) is 500 times greater than its minimum value, and these alternations take place slightly faster than 1 c/s (Dietrich, Lichtenberger, and Zinn, 1956 ; Cockcroft, 1957).

The last vibration problem to be mentioned here is a biological one. Helmholtz (1930) explained the physical mechanism of the ear (Bekesy, 1957) and of the vocal chords, organs of surpassing beauty and ingenuity of which our wonder and admiration increases the more we study their details. But their operation belongs to the realm of acoustics, which was not included in the subject matter of this lecture. The human heart, however, is a vibrating organ functioning at a frequency which does fall within our domain. A few years ago a specialist surgeon was considering an operation on a heart in which the central valve was leaking as a result of a history of " rheumatic fever." It was proposed to close the valve permanently by surgery and to connect the two chambers of the heart by a by-pass consisting of a short section of artery in which an artificial mechanical check valve was to be inserted. Among the many very difficult design problems of such a valve most were biological and some mechanical, and not the least one was that of the fatigue and wear strength of the element. While this was being discussed it was remarked that the human heart during a full lifetime performs 3000 million beats, a number far greater than that of any valve or other vibrating or reciprocating part in any machine made by human beings. Thus, in the presence of the very great recent accomplishments of our engineering profession and of science, we stand ever more humble and admiring in the contemplation of Nature's craft.

# Highway Needs of Great Britain

*Last week, from November 13 to 15, a conference on the highway needs of Great Britain was held at the Institution of Civil Engineers at which ten papers on various aspects of that subject were presented. Shortened versions of the introductory address to the conference, given by Mr. H. Watkinson, Minister of Transport and Civil Aviation, and of the closing summary, given by Sir Herbert Manzoni, city engineer of Birmingham, are given here.*

THE importance to the nation of an adequate road system, reasonably free from accidents and congestion, has once again been under discussion, this time at the behest of the council of the Institution of Civil Engineers. The reason for the conference is worth stating in full from the conference programme :

" With congestion and accidents on the roads growing at an alarming rate, one of the major tasks of the civil engineer in the next decade or two will be to build new and to improve existing highways. It is important to the nation that the problems and considerations involved in this task should be fully understood and discussed by engineers, so that they can play their full part in their solution. The council of the Institution has therefore arranged this conference to provide a forum for the discussion of the problems involved, which will not only be attended by engineers, but by others whose responsibilities may place them in a position to influence public opinion and policy on this great question."

Ten papers were presented, covering various aspects of the subject as follows :—The basic needs ; road construction requirements ; the need for research and traffic engineering ; resources, engineers, plant and materials ; and economic considerations. An abstract from one of the papers is printed on page 747.

### Opening Address

On Wednesday morning, the conference was opened by the Minister of Transport and Civil Aviation, Mr. Harold Watkinson, who spoke of the Government's plans for the construction of new roads, in the following terms.

" I have little sympathy for those who still say about roads ' would it not be better if,' whether the ' if ' is a committee or a study group or a change of plan or priority or anything else that will stop me and my department from getting on with the job. After all, we have lost fifteen years. Those years and the roads that should have been built in them are the measure of the immense task that now faces us. I can therefore sum up my personal and my official attitude to highway needs quite shortly : (1) Make a plan that will harness all the immediate resources of men and money ; (2) press forward and carry it out ; (3) for the longer term shorten the time lag in road schemes by ' pre-planning ' on a much larger scale ; (4) re-examine our future highway needs in order that the size of the task that still lies ahead can be accurately assessed. All these matters are well in hand.

" I gave the first outline of my immediate road plans to the Urban Motorways Conference just over a year ago. Since then they have, I think, become reasonably well known. Their basis is five major road projects.

" One will go from London to Newcastle and will be largely built on the basis of our existing road, the so-called Great North Road. One will run from London to Birmingham, embodying some 70 miles of continuous motorway, and then on with a further 100 miles of motorway from Birmingham to Preston. Another will be an improved route from London to South Wales, including a connection with London Airport and the Slough and Maidenhead By-passes, and eventually a Severn Bridge. The fourth will be a motorway from the Midlands to South Wales, and the fifth will give access from London to the Kent coast and the Channel port of Dover and Folkestone.

" Those are five major projects to which my Ministry are going to give overriding priority in our road construction in the next few years. Together they constitute the first stage of a national network of modern trunk routes. Their construction will go ahead as fast as all the processes can be pressed forward.

" Next comes the task of eliminating bottlenecks in urban areas by schemes both within and at the approaches to large cities and towns ; in addition, a number of by-pass schemes to enable through traffic to avoid congested areas, and improvements on existing routes to dual carriageway standards to make for ease of access.

" Thirdly, we are pressing forward with as many smaller schemes as we can afford up and down the country. This involves the widening and straightening of existing routes, the elimination of bends, the strengthening of weak bridges and the improvement of conditions at actual and potential ' accident black spots.' Progress on this programme is now being made rapidly. A number of schemes have already been completed, and many more are under construction.

" I hope that work will start this financial year on the London–Birmingham motorway and the Ross Spur road, both of which will be built to full motorway standards. The motor road from Birmingham to Preston is planned to start in 1959. A draft special road scheme for the Medway towns motor road will be published very soon now. This motorway will form a major part of the first-class trunk route to the Channel ports in the South East—a route which will become of very great importance if the Free Trade Area comes into being.

" On the Great North Road, much work is going on, and new schemes are being put in hand rapidly. Fifteen major schemes are in hand already, and forty-seven more are being prepared and will be started as soon as we can.

" A few of the urban schemes we are tackling are :—Birmingham Inner Ring Road : work is proceeding on the first section of this £15,000,000 scheme, which will eventually provide a 4-mile long dual carriageway around the main business area. The Stretford–Eccles By-Pass is to be built as a motorway and is the first one in the country for which a local highway authority —in this case, the Lancashire County Council—is responsible. Work started in April this year on the first stage, which includes the Barton high-level bridge over the Manchester Ship Canal, and it is hoped to complete this section in 1960. It will ultimately form part of the Manchester outer ring road.

" New Park Lane scheme : This has been approved by the Government with the addition of an underpass linking Piccadilly with Knightsbridge.

" It involves complete reorganisation of traffic on the east side of Hyde Park and in Park Lane, as well as Hyde Park Corner and Marble Arch.

" The next important stage of this scheme is to get legal powers, and a Bill will be laid before Parliament to-day. Notting Hill Gate : work on the reconstruction of the Underground stations is in progress following considerable demolition of property.

" Roadworks to remove this notorious bottleneck will follow.

" As you know, road building is a costly business, and even the schemes to be authorised for the four years from 1958/9 to 1961/2 of the programme I have outlined will cost the Exchequer some £240 million for England and Wales alone (schemes in Scotland over the same period will cost some £40,000,000). Some will say that this is not enough, but my view, speaking as a Member of the Government, is that roads are now getting their fair share of the nation's resources, and I am not prepared to ask for more for the time being. We must not forget that, in addition to these

sums for major schemes and new works, we are spending very heavily on maintenance and minor improvements, too. Including local authority expenditure our total expenditure on highways this year will be well over £100 million for England and Wales alone."

### Closing Summary

At the final session of the conference, on Friday afternoon, Sir Herbert Manzoni gave an address in which he summed up the whole problem; abstracts from Sir Herbert's address are given hereunder.

The fact that 13½ per cent of the national income is spent on road transport probably makes it—I have not verified this—the largest single item of percentage of our national income of almost any activity in this country. The 1956 figures for vehicles on the road are given as nearly 7,000,000—6,916,000—and those vehicles covered over 54,000 million miles on 190,000 miles of road in this country. We are told that 27 per cent of the total mileage is by commercial vehicles and—what is very important—50 per cent of the mileage of passenger vehicles is on business.

If, then, our road transport is such a very large, very important and indeed essential item, what is the state of the roads which carry it? We have had figures given to us, mainly by Glanville and Smeed, who tell us that 1 per cent of the road system carries 25 per cent of the traffic, and 1 per cent of the road system is only 1900 miles. Ten per cent of the road system, which is only 19,000 miles, carries 60 per cent of the traffic.*

On certain straight lengths of our rural roads which are in good condition and of adequate width we manage to get speeds of this order: private cars, 48 m.p.h.; light goods, 40 m.p.h.; medium goods, 34 m.p.h.; heavy goods, 27 m.p.h. The present average speed on our trunk roads is 36 m.p.h. and on our Class I roads 33 m.p.h., going right down to 25 m.p.h. on our unclassified roads. It is stated that 30,200 million miles are travelled on our rural roads at an average speed of 32 m.p.h., and on our urban roads, on which, surprisingly enough, the mileage travelled is 24,800 million miles—almost as much as on the rural roads—the average speed is only 20 m.p.h., while in cities such as London and Birmingham the average is down to 6–8 m.p.h., and even in towns such as Worcester and Stafford it is only 12–14 m.p.h.

We are told that if those speeds could be increased by only 1 m.p.h. the saving would be no less than £36,500,000 per annum, and that makes no allowance for non-working time. We are also told that, assuming average speeds of 25 m.p.h., in urban areas (which is probably reasonable), and 40 m.p.h. in rural areas (which is probably far too low), there would be a saving of £155 million per annum, again with no allowance for non-working time. Brunner tells us that this estimate is very conservative; if certain other factors are brought in, it is £540 million per annum.

*Accidents.*—We are told by Drake that the rate of injury accidents per million vehicle miles on dual-carriageway roads, from some observations which he has made, is 1·5, and that it is 1·8 on single-carriageway roads. The estimate for motorways, taken from Continental experience, is 0·4. Glanville and Smeed give us some supporting figures which are similar. Drake gives us a very interesting example, of the Liverpool-East Lancashire road over a period of three years, and works it out in this way. There were 222 accidents on that road in three years. If that were a motorway, he says, there would be no pedestrians on it, and that fact would reduce the 222 to 145. If it were a motorway, crossings would be eliminated, and this would further reduce the figure to eighty-seven. If it were a motorway with dual carriageways there would be no head-on collisions, and the figure would come down to forty-two. That is factual; it is a process of elimination of the causes of accidents, bringing the figure down from 222 to forty-two. It is a very striking verification of the percentage figures given earlier in the paper. We are told also that an expenditure of £490,000 on a few road works which have been done and assessed saved 121 personal injury accidents, which represents about £4000 per accident. These are very striking and interesting figures. We are told also that, as traffic increases, so the proportion of pedestrian accidents decreases, while the driver and passenger casualties increase. That is logical, of course, and it is part of the case for doing something to improve our roads.

What about the cost of these accidents? This is obviously difficult to estimate. Glanville and Smeed estimate £110 million per annum; Brunner brings it out at £169 million per annum and then gives us a very interesting check on that when he says that the amount spent on insurance against accidents is probably of the order of £200 million per annum.

*The Loss to Industry.*—Taking delays and accidents together, on the most conservative possible basis and without including non-working time, we get a total loss of £265 million per annum, due to our present inadequate roads. That is a financial measure of the need to do something, quite apart from such things as pain and suffering. What I cannot understand is why the one section of our people who could say the most with the greatest weight about these matters, industry, does not do so. Here we have an apparent loss which I work out at 1½ per cent of our national income—an enormous figure. If all our goods, for export and home consumption, but particularly for export, carry a 1½ per cent excess, as it were, due to the inadequacy of our roads, I cannot understand why industry does not speak with one voice and ensure that something is done. I know that the memorandum of the Federation of British Industries did a great deal towards securing the increases in the road programme which we have seen in the last year, but I should have thought that industry could do something even more effective than that. In my experience, industry is probably too individualistic to do very much in common.

*An Adequate Highway System.*—Glanville tells us that motorways often show large savings in operating costs over all-purpose roads, because the capacity is greater, speeds are higher and accidents fewer. Brunner tells us that motorways use 14 acres of land per mile, the agricultural productivity of which has a value of about £840 per annum, whereas the motorways can save as much as £30,000 per annum per mile. Colin Clark, an agricultural economist, tells us that improved traffic facilities are essential for agriculture and that the amount of land used is comparatively unimportant. With all these assurances, I think we can say that we agree that we need 800 miles of motorways.

We then come to the urban requirements, and these are very varied. A description of them was given by Nicholas in these terms:

"The provision of continuous ring roads and thereby the elimination of through traffic—involving as an essential feature the prevention of direct movement through the urban centre. The elimination of parking on main urban roads. The elimination of pedestrian or vehicular access from building frontages on main urban roads, and particularly the elimination of all shopping frontages."

To this summary Mr. Nicholas has now added a very important item, the complete segregation of pedestrians on major roads in congested urban areas. That, I think, must be a feature of all major urban roads. Very little is said about car parking.

With regard to rural roads, we are told that of the 7000 miles of trunk roads about 1000 miles will probably be replaced to motorway standards. We have 20,000 miles of Class I roads, and Nicholas and Wilkes tell us that about 8 per cent, or 1600 miles, should be improved to dual carriageway standard, and 11,000 miles, or 55 per cent, to three-lane width. They then tell us that on the 160,000 miles of minor roads we shall have to do a great number of minor local improvements in widening, straightening and general alignment. Added to that is the programme of major works such as tunnels and bridges. That gives a general picture of what we need to do to deal with our present road system.

What should be the basis of design of all these works? I think we can say quite definitely that the only certainty in this matter is that the traffic will grow more quickly than anyone is likely to estimate. One vehicle per family seems to be the only sort of ultimate on which we can fix with any reasonable certainty. I believe the average opinion would be, therefore, that we ought to allow for a doubling of the number of vehicles within about ten years and allow some margin in our widths.

*The Cost of an Adequate System.*—What would be the cost of such a system of roads? We have only two real estimates. One is that made by Nicholas and Wilkes, which totals £3500 million, and the other is that envisaged by Drake over a period of twenty-five years, which comes to £4400 million. They may well both be right, because if we look ahead for twenty-five years we shall undoubtedly need a greater expenditure in total in that time than if the work was carried out in a shorter time.

That brings me to the important item of timing. In what time should we carry out this work? No strong opinions have been expressed on this point. Drake has talked about twenty-five years and an expenditure of £175 million per annum, but, if we are to catch up with the traffic problem, we have probably to think of a shorter time than that; in fact, if we are going to complete a system which will handle the traffic which doubles itself in ten years, we ought to spend that money in ten years. That would give us a rate of £350 million per annum, which is less than the expenditure on power, although it is rather more than the expenditure on railways. In that time on the most liberal estimate we should have saved the whole of the expenditure, but on the worst estimate of only £265 million, which most speakers in this conference have recognised as being conservative, it would require another eight years thereafter for the scheme to pay for itself. That, of course, is in money.

Have we the resources to carry out such programmes? Harding has based his paper on the Minister's present programme and has not analysed in detail any faster rate of expenditure. From the details which he gives, however, I think there is very little doubt that in the matter of materials and plant we should probably have enough to carry out a programme in ten years at a cost of £3500 million. We should use a fair

* For further figures of this nature see abstract on page 747.

percentage of our plant, but I think that it would be possible, especially if the planning were well conceived. We should be using, I estimate, something like 100,000 men out of a total in the building and civil engineering trades of 1,400,000. That is not a very big percentage, if the work is given proper priority in relation to other schemes. There are, of course, such items as steel, which may be difficult ; but, if we were going to undertake a programme of this size, we should probably have to time its commencement rather slowly over the first year or two and build up to a steady rate.

Those seem to me to be the important items which have arisen at this conference. I am not going to attempt to deal with the other papers, valuable though they were, except to say this. Lovell has brought into question the whole of the organisation in this country to carry out a programme of roads. I do not know what programme he had in mind. The opinion has been expressed that the present organisation can do the job. Personally, I am very doubtful whether the present organisation could do the job if it is going to be done in ten years at a cost of £350 million per annum. If such a programme, or anything of that order, were envisaged, he may have pointed to a very important fact, that such a programme would probably have to be carried out by an organisation newly set up for the specific task.

# Road Transport and the National Economy

By W. H. GLANVILLE, D.Sc.,* and R. J. SMEED, Ph.D.†

*We reproduce here the conclusions from a paper entitled "The Basic Requirements for the Roads of Great Britain," presented last week at the Institution of Civil Engineers' conference on the highway needs of Great Britain. In the full paper, the authors discuss the shortage of basic information, especially about urban traffic, which is needed to assess the economic position of road transport and of new roads, and give detailed arguments showing how their conclusions are reached.*

THE need for road transport to be recognised as a primary element in the national economy is shown by the fact that expenditure on road transport now runs at more than £2000 million per annum, is increasing every year, and at present absorbs 13·5 per cent of the national income. Expenditure on goods transport by road constitutes nearly half the total.

Analysis of Ministry of Transport and Civil Aviation figures of traffic and road width in rural areas indicates that on trunk and Class I roads, 1 per cent have dual carriageways or single carriageways at least 40ft wide, 10 per cent are less than 40ft but at least 30ft wide, 67 per cent are less than 30ft but at least 20ft wide, and 22 per cent are less than 20ft wide. Class II roads are considerably narrower, 64 per cent being less than 14ft wide.

Another survey indicates that 1 per cent of the whole road system carries 25 per cent of the traffic and more than 10,000 vehicles per day, 10 per cent carries 60 per cent of the traffic and more than 3000 vehicles per day. On the other hand, the least busy 50 per cent of the road system carries only 5 per cent of the vehicle-mileage and less than 500 vehicles per day. The traffic over a considerable mileage of these trunk, Class I, and Class II roads is thus very light, and a large proportion of the traffic on the roads would be affected by improving a small proportion of the road system.

### Vehicles and Vehicle Mileages

The number of motor vehicles registered in Great Britain has increased fairly steadily since 1946 at the rate of 8·2 per cent per annum at compound rates, and, at this rate, will double in nine years. Vehicle-mileage on the road system has been increasing by about 7·4 per cent per annum since 1950, although in congested areas, such as Central London, the increase has been less ; this is equivalent to doubling in ten years' time. Consideration of present trends of changes in vehicle ownership with income and of vehicle ownership in other countries suggests that the present rate of increase in the number of vehicles using the roads will continue. These facts emphasise the need for urgency in dealing with the problem.

The economic importance of reducing delays to road traffic is illustrated by the following facts :—

(i) 27 per cent of total vehicle-mileage is performed by commercial vehicles.

(ii) 50 per cent of the drivers of private cars travelling on roads between London and Birmingham during working hours were travelling on business. Results of a questionnaire to a sample of London residents on their travelling habits between 9 a.m. and 5 p.m. on week-days, suggest that 5 per cent of bus passengers, 27 per cent of car drivers, and 22 per cent of taxi occupants are travelling in working time.

(iii) When the speed of traffic in urban areas is reduced by congestion to 10 m.p.h., petrol consumption per mile travelled is increased by about 50 per cent when compared with the consumption at 20 m.p.h.

(iv) Tests with two cars to compare running conditions on a motorway with conditions on a trunk rural road suggest that use of a motorway at the same average speed as a trunk road would save about 24 per cent in petrol consumption. If speeds were increased under motorway conditions to give the same petrol consumption as on a trunk road the journey time would be reduced by 25–40 per cent, depending on the type of car used. Further tests, especially with commercial vehicles, are required.

It is estimated that 25,000 million miles were run by motor vehicles in 1956 in urban areas at an average speed of 20 m.p.h., and 30,000 million miles in rural areas at an average speed of 32 m.p.h. It is also estimated, making no allowance for non-working time, that £7,000,000 per annum in rural areas and £29,000,000 per annum in urban areas would be saved if traffic could be speeded up by 1 m.p.h. It is further estimated that if the speed of traffic under congested conditions were raised to the speed under light traffic conditions there would be a saving to the country of about £155 million per annum, again with no allowance for non-working time. If non-working time is valued at the same rate as working time, the estimated cost of congestion rises to £465 million per annum. These costs are now increasing at rather more than twice the rate of growth of traffic, namely, at more than 14 per cent per annum.

### Road Accidents and Their Cost

It is estimated that in 1956 road accidents caused damage to property to the value of £27,000,000, that the medical treatment of the resulting casualties cost £9,000,000, and that £40,000,000 loss of output was caused by absence from work due to injuries resulting from accidents. The total measurable economic cost of road accidents is estimated at £70,000,000 in urban and £40,000,000 in rural areas. The suffering involved cannot, of course, be put into monetary terms, but court awards which make some allowance for this are, on the average, about 50 per cent more than the direct economic cost of accidents. This total economic cost of accidents is increasing at the rate of £7,000,000 per annum at current monetary values.

A sample of road works undertaken during the past few years has been investigated to find the effect on accidents. Most of the work results in a decrease in accidents but some types of changes resulted in an increase. For those types resulting in a decrease (except the resurfacing of slippery roads) and for which information on costs is available, it is estimated that 121 personal-injury accidents per annum were saved by an expenditure of £490,000, i.e. an expenditure of £4000 resulted, on the average, in a saving of one personal-injury accident per annum.

One of the most rewarding forms of treatment is the roughening of slippery surfaces. This is not included in the foregoing. The cost of treating the road surfaces at places where accidents involving skidding are common averages one-tenth of the monetary saving from the reduction in accidents during the year following treatment (i.e. the yield is 1000 per cent in the first year).

The total number of personal-injury accidents per mile travelled is much less on motorways than on other roads. But since the number of fatal accidents per mile travelled is very low on highly congested urban roads, the fatal accident rate is not always lower on motorway than on urban roads. Fatal accident rates are, however, much lower on motorways where speeds are high than on ordinary roads where speeds are more moderate but where there is considerable pedestrian and cycle traffic.

Unless special steps are taken, the likely increase in traffic can confidently be expected to result in an increase in accident frequency. Between 1952 and 1956 the mileage travelled by motor vehicles in Great Britain rose at the rate of 7·4 per cent per annum. During the same period the average rate of increase in fatalities was 3·4 per cent per annum, the increase in serious casualties 5·1 per cent per annum, and in reported slight casualties 7·1 per cent per annum.

Analysis of the accident experience in many countries has shown that, as traffic increases, the proportion of pedestrian to total casualties falls and the proportion of motor-driver and passenger casualties increases. Since 1952, pedestrian casualties have risen at an average rate of 3·1 per cent per annum, pedal-cyclist casualties by 1·0 per cent per annum, motor-cyclist casualties by 10·6 per cent per annum, and other motor-vehicle-driver and passenger casualties by 10·0 per cent per annum.

The likely tendency for an increase in the proportion of motor-vehicle casualties emphasises the importance of straightening roads,

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of building dual-carriageway roads, and of reducing the overcrowding of single-carriageway roads, all of which it is believed would reduce the proportion of head-on collisions and thus eliminate the more serious motor-vehicle casualties. This likely tendency also shows the importance of limiting speeds on high-speed roads, and also of the importance of designing vehicles in such a way as to reduce the injuries sustained by their occupants when they are involved in collisions.

There is a tendency for an increasing proportion of accidents to take place in non-built-up areas. If present trends continue for another eight years the majority of fatalities will be taking place in rural areas.

### Economic Return of Motorways

A sample investigation indicates that, for rural roads, the traffic on 62 per cent of trunk roads, 23 per cent of Class I roads, and 6 per cent of Class II roads now exceeds the design capacity of those roads as given in Ministry of Transport and Civil Aviation Circular No. 727. The traffic on 13 per cent of trunk roads exceeds twice the design capacity. The length of these roads which is now loaded to beyond design capacity is about 8000 miles and is increasing by about 700 miles per annum.

It is estimated that provision of the required additional lanes for these rural roads might cost about £420 million. Allowing for a possible doubling of traffic, £1200 million might be needed to catch up within ten years. To set against these sums there should be some savings from accidents and from the speeding-up of traffic. The speeding-up would be expected to save, as a minimum, £45,000,000 per annum owing to an increase in speed of 8 m.p.h. (the difference between present and free-running speeds). If the expected additional slowing-down due to increasing congestion over the next ten years on the existing system is allowed for, the saving in operating costs might be four times this figure. These savings do not allow for time saved during travel in non-working time. The total savings would then be between £180 million and £540 million per annum, allowing for non-working time.

Motorways often show large savings in operating costs over all-purpose roads, since capacity is greater, speeds higher, and accidents fewer. No very precise figures can be given, for circumstances differ from road to road; but on the not unreasonable assumption that 35 m.p.h. overall average could be attained on an ordinary road, and 45 m.p.h. on a motorway, the saving in operating costs for a motorway over an all-purpose dual two-lane road would be about £3600 per mile per annum at the traffic volume just sufficient to justify a dual carriageway in rural areas and £10,000 per mile per annum at the limiting design capacity for a dual carriageway road. On this basis, a difference in capital expenditure (at 5 per cent return) of between £72,000 and £200,000 per mile would be justified. These figures do not include the saving from accidents and no allowance is made for the additional capacity of the motorway or for savings in non-working time.

Investment in road improvements in Great Britain since the war has been small compared with that in other countries, but this does not apply to maintenance expenditure. This is reflected in the high standard of the surfaces on the roads of Britain. There is a need to keep the relation between expenditure on improvements and on maintenance under review, particularly since reconstruction of roads on the same alignment and resurfacing of roads—other than the slippery ones—can lead to an increase in the number of accidents.

The economic return from projected and actual road improvements has been estimated in nine cases. Making no allowance for non-working time, four of the schemes gave returns of less than 3 per cent, but three of the remainder gave returns greater than 15 per cent. The returns obtained thus show some schemes to be much better than others and there is a need to make sure that such funds as are available for roads are spent to the best advantage. With this in mind, a system of assessing priorities, based on economic returns, is under trial to help in the selection of schemes.

### Benefit of Urban Motorways

Many of the above results relate also to the question of highway needs in urban areas and reinforce the conclusion in the review given to the 1956 Conference on Urban Highways. It was then concluded that improvement of existing urban roads can have only a limited effect, that the benefits to be obtained from urban motorways are considerable, that they should be planned in relation to the overall needs of transport, and that building them would have immediate and increasing benefits as the system, with parking and loading facilities, is developed. There is, however, a need for more facts, and large-scale surveys are required before the problem can be adequately assessed; it is clear that until this is done many schemes for road building must be largely a matter of judgment helped by only a few of the facts required.

It is not possible to describe fully the basic requirements for the roads of Britain without a great deal more information than is at present available. One of the greatest of the basic needs is, therefore, for more factual knowledge about the road system, about the traffic it carries, and about the origin, destination and purpose of the traffic. Many of the estimates made in the paper suffer from lack of precision, but it is believed that they are the best that can be given now.

## Lloyd's Statistical Tables

Lloyd's Register of Shipping has issued its *Notes on Statistical Tables*, 1957, which are based on entries in Lloyd's Register Book at July, 1957. The total world tonnage is given as 110,246,000 tons gross, representing an increase of 5,046,000 tons, compared with 1956, of which 1,882,000 tons is under the Liberian flag of convenience, with the remainder distributed among the principal maritime nations, with Norway leading with 453,000 tons.

Since the war, the largest amount of tonnage built comes within the size group 10,000 to 15,000 tons, 75 per cent of which are oil tankers, while 84 per cent of the ships of more than 15,000 tons and under five years of age are oil tankers. The oil tanker tonnage has increased by 1,727,000 tons since 1956 and now totals 29,938,000 tons gross, or 27·2 per cent of all shipping compared with 26·8 per cent of a year ago. Again, Liberia, with 959,000 tons, claims more than half of the world increase. Great Britain and Northern Ireland's tanker fleet amounts to 5,586,000 tons, followed by Norway with 4,747,000 tons, Liberia with 4,143,000 tons, and the U.S.A. with 4,143,000 tons. Ships propelled by steam reciprocating engines totalled 35,938,000 tons gross, the corresponding figures for turbine machinery being 31,313,000 tons and for diesel engines 40,953,000 tons. Of the total of steam-propelled ships, 60,760,000 tons are oil-burning. Merchant ships entered in the Society's Register Book totalled 10,555 of 47,100,000 tons gross.

## Training of Indian Supervisors for Durgapur Steel Works

Nineteen Indian university graduates who have arrived in the United Kingdom for training, under the Colombo Plan, to fit them for supervisory positions in the new Indian steel works now being built at Durgapur by British firms, were welcomed by Mr. C. J. M. Alport, M.P., Parliamentary Under-Secretary of State for Commonwealth Relations, at a reception held in the Commonwealth Relations Office recently. These nineteen trainees are the advance guard of 300 who will be coming to the United Kingdom for training over the next three years.

To carry out this steel works project, thirteen leading firms in the United Kingdom have joined forces to construct the plant and install the equipment. Private interests in the United Kingdom are providing a loan of £11,500,000 and a further £15,000,000 credit has been made available by the U.K. Government. The production capacity will be 1,000,000 tons of steel a year. In three years the works will begin to function. In the meantime, the British Government is providing under the Colombo Plan specialised training for the future supervisors. This is a combined operation between Government and private industry. The actual training facilities are being provided free by the British steel industry and ISCON (the consortium of manufacturers of the plant); advice on the training programme is being given by the British Iron and Steel Federation, while the cost of journeys and maintenance of the trainees is being borne by the United Kingdom Government.

## British Standards Institution

*All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.*

### LIQUID STARTERS AND CONTROLLERS

No. 140 : 1957. Price 5s. This is the second revision since 1923 of B.S. 140; it follows the publication earlier this year of revised British Standards for motor starters and controllers and for field rheostats, and thus completes an up-to-date series for motor control gear and related equipment. B.S. 140 : 1957 applies to liquid starters and controllers for the rotor circuits of slipring, synchronous induction and similar motors. Its scope has been extended to include equipments used for d.c. dynamic braking, reverse-current braking and slip regulation. The basis of the standard ratings of both liquid starters and liquid controllers is specified, and standard sizes of liquid starters and controllers are recognised in terms of motor horsepower. Requirements for the temperature of the electrolyte at the maximum rate of dissipation and the cooling water circulation are also included. The design and constructional requirements cover many aspects, such as provision for earthing and earth continuity, limitations on the initial and the maximum motor line current, and the operating gear and interlocking devices. Full details are included of the type and routine tests which the equipment must satisfy in order to comply with this standard. Two of the four appendices contain information and formulæ for the estimation of the horsepower-minutes capacity of liquid starters and of the horsepower dissipation of liquid controllers in terms of the motor rating and the required conditions of starting and speed control.

### ATTACHMENT AND ENVELOPE DIMENSIONS FOR GENERATORS (DYNAMOS) FOR I.C. ENGINES

No. 2895 : 1957. Price 4s. 6d. This new Standard is one in a series relating to the components of internal combustion engines. It has been prepared to make possible the maximum degree of interchangeability of generators fitted as auxiliaries to such engines. The standard applies to d.c. generators of 6V, 12V, 24V and 32V nominal output, and having nominal diameters of from 4in to 8in. The types dealt with are: ventilated, totally enclosed, fully-screened and waterproofed, which may be swung, cradle or flange-mounted. While the attachment, envelope (including terminal boxes) and shaft-end dimensions for these generators are specified, the standard does not give details of electrical characteristics or such special features as requirements for screening or waterproofing.

# Vacuum Techniques in the Atomic Energy Industry

No. II—(*Concluded from page 705, November 15*)

*In a paper presented on November 8 at the Institution of Mechanical Engineers (in conjunction with the British Nuclear Energy Conference), vacuum techniques were classified as those used* (1) *where a vacuum is required as an essential part of the process, and* (2) *to ensure the tightness of plant which may not finally be required to operate under high-vacuum conditions. Advances in technology have made the construction and testing of plant to vacuum standards a relatively simple matter. The paper, by Dr. H. Kronberger, was reproduced in a shortened form in our last issue, and the discussion that followed is reported briefly below.*

PROFESSOR O. A. SAUNDERS, vice-president, was in the chair at a general meeting of the Institution of Mechanical Engineers arranged in conjunction with the British Nuclear Energy Conference on November 8. After Dr. Kronberger had presented his paper "Vacuum Techniques in the Atomic Energy Industry," it was discussed at some length, and a record of part of this discussion follows.

Mr. A. S. D. Barrett : I am glad to open the discussion because I believe that this is the first time that a paper on high vacuum technology has been given before the Institution. That it should be given by a physicist is perhaps a reflection on mechanical engineers, or, what is better, it may show the close integration nowadays of the technologies. However that may be, this is an important paper because it shows the way in which high vacuum technology is entering profoundly into many industries with which the mechanical engineer is concerned.

The atomic energy projects have had a colossal effect on industry generally. High vacuum technology would not be what it is without the great stimulus which atomic energy provided. One of the things which it has done has been to give us a technique for proving tightness. Mechanical engineers will be interested to know that, for example, the oil drum is now being tested by vacuum techniques, not necessarily the same as those for use with atomic energy, but borrowed from this field. In the automobile industry, cylinder blocks, pumps, and so on, are now being tested by this technique. It is interesting to bear in mind the stupendous effort required to vacuum test hundreds of components, but we are able to-day to use what is almost automatic plant, in which the operator places the component on the table and, by pressure and time switches, tests it on a "go" and "not go" basis. In our own factory we are regularly concerned with vacuum standards some hundred times that which was used for atomic energy, and, just as on the atomic energy project, we have semi-skilled people dealing with this by almost automatic means. That is a very good thing, because otherwise the cost would be prohibitive.

We make extensive use of hydrogen in most of the techniques. Factory inspectors have tended, because they do not quite understand this, to think of hydrogen as a very dangerous gas, when, in fact, it is not. Recently I had an interesting discussion with a very learned factory inspector, who suggested—it is unusual to have such co-operation from factory inspectors!—the use of a radioisotope for a detector, because he feared that hydrogen was unsafe. He did not altogether believe me when I pointed out that the dangers of using such an elegant technique would be far greater than the occasional *poof* that one may have with hydrogen, and so I recommended him to get in touch with the author, from whom he got the same reply, and was satisfied.

Gaskets are very important in vacuum engineering. I wonder whether technology has reached a stage where the author can give us some idea, in view of the multitudinous designs now being put forward for metal gaskets, of what the people concerned with atomic energy regard as a standard ? The way in which high vacuum engineers have solved problems relating to the shaft seal and the vacuum seal has been remarkable. We know that the author has some wonderful seals on some of his projects ; can he tell us more about them ?

He has referred to the important question of the joining together of metal parts, and has laid down some very good rules, which I think are, by and large, accepted practice. Vacuum technique has itself introduced a new technology which may help us, namely, vacuum metallurgy, and gives us precise ways of joining things together free from joining troubles. I should like to know to what extent the Atomic Energy Authority now uses vacuum in its jointing techniques. I have in mind vacuum brazing, and so on.

Professor J. M. Kay : The Atomic Energy Authority has been curiously reticent up to now about its achievements in the Capenhurst diffusion plant. This paper is of special interest and value because, for the first time, it gives an account of some of the engineering problems associated with this very remarkable project. There are, of course, many other engineering problems in the Capenhurst plant which the author has not described, but I hope that this paper will be followed by others. I would mention in particular some of the problems associated with the compressors and the glands or shaft seals and bearings. One can understand the need for secrecy on certain matters relating to diffusion plants, but I am sure that there are many design features and many special techniques which may have a much wider application, and I believe that it will be very much in the national interest if industry can be given more information.

Many of the recommended principles of design, and the author's suggestions with regard to practice, are also relevant to the problems of the $CO_2$ gas circuits in the large gas-cooled power reactors. I am particularly glad to note his comment that vacuum tightness starts at the drawing board and that the successful and economic operation of vacuum plant depends on good design more than on anything else. I believe that this statement sums up the whole problem, and that it applies with equal force elsewhere in the nuclear energy industry. Engineering has always been and always will remain an art. The engineering designer in these days, however, must base his art on a full understanding of the new principles and problems which are continually arising. The author may have described himself as a physicist, but I prefer to regard him as an engineer.

Mr. J. Blears : We have found increasingly as time has gone on that it pays to have very complex leak-testing systems. We have in use a differential Pirani system, which is mentioned in the paper, and use a six-head machine, which is probably the only example in operation in the world, and which is still giving very good results. Since about 1954, however, we have in our own factory taken the plunge and now operate with mass spectrometers. I think that the results which we are getting prove beyond any doubt that this is the most practical method for anyone with a great deal of work to do. From a twelve-head machine with a Geissler tube as the indicating device the output is 4000 pieces of equipment a year, and the leak standard is $10^{-3}$ lusecs. A five-head machine of the differential Pirani type is giving an output of 3000 pieces a year with the same standard of $10^{-3}$ lusecs. (The lusec is not a good unit ; it is necessary to subdivide it again, and it is time that it was buried.) A single-head mass spectrometer is turning out 13,000 pieces of equipment per year to a standard of $10^{-4}$ lusecs, and another mass spectrometer, working with a much higher standard, of $10^{-6}$ lusecs, is dealing with 1500 pieces a year.

We find that the capital charges for the twelve-head machine and the single-head mass spectrometer are about the same, and one man can deal with each ; but there is no question about the numbers of pieces or the economics, and the problems of maintenance are not very great. We, like everyone else, tend to use labourers as leak detectors, and after quite a short time they are able to look after their equipment as well as their leak detection problems.

It is usually assumed that if mass spectrometers are employed it is necessary to use helium, but this is false. In our factory we use coal gas on the mass spectrometers as the probe material, the methane acting as the search gas. We are now considering the problems involved in an output of 600 pieces per hour on a multi-head machine with a mass spectrometer, fully automatic, so that component testing should be under better control in the future.

Mr. T. B. Kent : I wish to emphasise that the particular problem dictates the method of vacuum testing to be used. We should not have the idea that the hydrogen-palladium method or the differential Pirani gauge method is of little use compared with other methods, but when dealing with small and relatively dirty components, containing oil and so on, the charcoal-Pirani method has been found satisfactory and cheap. That does not mean that we cannot use a hydrogen-palladium gauge if we go to a good deal of trouble, and it has been done and is a perfectly good method, as is the differential Pirani method and the mass spectrometer method.

Dr. E. J. Burton : We may expect that improvements in welding techniques will show marked improvements in vacuum standards. This is brought out in two ways. First, if a weld fails to pass the acceptance test it is generally due to a fairly large hole, due probably to a relatively gross error of technique, rather than to a large number of small holes. Secondly, welds show a very high acceptance rate ; recent data show that only one weld in a hundred fails.

Mr. H. Ochert : If rejection is to be carried out at a certain rate it is necessary to be able to test at a higher sensitivity and at a quite high rate of production, and to do this a more sensitive method of leak detection is required in order to have some sensi-

tivity in hand. The method with which I am most familiar, the palladium-hydrogen method, is therefore in some ways the method of choice. Poisoning by impurities can be eliminated by the almost universal use of a liquid air trap as protection, and putting it between two diffusion pumps also helps. One of the things, however, which very often limits the life between reactivations of this method, or the Pirani-charcoal method, is the kind of cleaning solvent used after the welds have been made. The usual ones, trichlorethylene and carbon tetrafluoride, may poison. Is there any hope of using other liquids which are not so bad, such as halogens ? Another point is that when charcoal is used it tends to saturate with water vapour, which may even permeate through the seals in common use. When saturated with water vapour the sensitivity changes enormously.

With regard to the figures given by Mr. Blears of numbers tested, I would point out that in another industry—the aircraft instrument industry—it is now common to use vacuum testing methods, of sensitivities higher than those mentioned, for testing instruments. Plants have been developed for this, small automatic manifolds which sit on top of commercial standard vacuum leak testing plant, and they work at rates approaching those mentioned.

We have observed that the leaks do not occur over a continuous spectrum of magnitude. There are certain common values, and I find that in welded joints leakage rates of the order of $2\text{–}3 \times 10^{-2}$ lusecs and $10^{-3}$ lusecs are the most common. I wonder whether that is the experience of others who have observed the testing of a very large number of components ?

Mr. R. Livingstone : For many industrial purposes castings can be of immense advantage, especially where there are corrosion hazards. I do not suggest that there is no danger at all from porosity, but if it does occur the usual impregnation offers a satisfactory cure in the majority of cases, provided it is properly executed. By " porosity " in this connection I refer to the porosity which will cause a leak *through* a casting. Surface porosity, which may retain contaminants, is not so easy to cure, but impregnation techniques are available to cure even some of these problems. From our own experience I would say that if the design of the vacuum container lends itself to manufacture as a casting one should not immediately discard the idea, but carefully assess the various problems involved.

Mr. M. E. Reed : Although gas and metallic arc welding can be and frequently are used for mild steel, the danger of flux and oxide inclusions is always present, together with the fear of distortion. As the author says, by the use of argon arc welding most of these troubles can be minimised. I should like to know whether the author has had any great success with the argon arc welding of mild steels.

For large, regular shapes continuous automatic machines are of great importance, and it is possible to obtain good vacuum welds, mainly due to the degree of control possible and the elimination of the human element ; but there is no such machine on the market, I think, for small fabrications. With all these modern techniques it is essential to obtain penetration welds and thus eliminate gas and dirt traps.

In Fig. 1, showing the correct designs for welding, the third, fourth and sixth illustrations show intermittent welds on the side away from the vacuum area. This type of weld introduces difficulty in locating the point of leak accurately. The tracer gases pass rapidly round the crevice between the welds, in some cases for a considerable distance. How can this difficulty be overcome ?

Once a leak has been located in a weld, it is generally recognised that it is advisable to grind the afflicted area away before rewelding, rather than try to patch over the leak, frequently causing a spread of the main leak into a number of smaller ones.

Mr. K. E. Latimer : I should like the author to say a few words on systems in which there is a high pressure on the outside and the vessel walls are comparatively thick. There is, for example, the application of submerged amplifiers, where we have ¼in thickness of steel and 4½ tons per square inch pressure of water on the outside. In the first place, I am not very impressed by the arguments about the geometrical size of the leak. I cannot imagine a leak of a constant diameter running through the whole thickness of ¼in. Secondly, I wonder whether the author has ever encountered pressure-sensitive leaks where, when the pressure is applied, the leak either closes up or opens out ?

If we want to test at 4 tons per square inch and apply tracer gas at that pressure, and we have an irregular object and a large pressure vessel, and therefore a large volume of gas, we have to consider the possibilities of explosion, which can be quite serious. We may then think in terms of halogen testing, but halogen is apt to attack O-rings and things of that kind. I am afraid that all of us in my firm have had a long series of difficult problems with hydrogen-palladium, hydrogen-Pirani, direct detection in water, and so on, but we should very much like to hear the author's views.

Mr. R. S. Hayward : The author mentions investigating leaks in a tube of 1¼in diameter and 300ft in length. I should welcome information about the time taken for a leak of, say, 2 to 3 clusecs at one end of this tube to reach the other end, if it appears that the mean free path factor is tending to be overwhelmed by the intricacy of the object concerned. In other words, how far do the geometrical parameters of the object affect the time factor ?

I should welcome any information on failure in welded tubes, and whether this depends on how the welder is feeling that morning. Are these failures completely random, or is there any system evident ?

With regard to the hydrogen-charcoal method, which seems to have the advantage over the hydrogen-palladium method in simplicity, cheapness and apparent reliability, can the author explain why charcoal is necessary at all and why a suitably designed standard cold trap cannot be used ? It seems that all gases except neon would be removed. Is there some factor against its use ? The other point in this connection is, how does one tell when the charcoal is flooded with gases other than hydrogen and can absorb no more ? Is there any reason why one should not carry on testing and pass objects as vacuum-tight when the charcoal is incapable of absorbing any more gases ?

Turning back to the question of having a long tube, say, 300ft long, or any object which provides an intricate path for the tracer gas, has the author had any success introducing a tracer at one end and measuring the air pumped out at the other end ? Assuming incompressibility, presumably what comes out at one end is equivalent to what goes in at the other. This should obviate the need to wait for the tracer gas to reach the vacuum end.

The Author : Mr. Barrett's question of what constitutes a good metal gasket is, of course, one which has interested me a good deal. Most of our gaskets are designed by intuition. It is obviously necessary to avoid exceeding the yield point of the metal used. (If some fundamental work on the subject is stimulated by this paper I shall be very interested.) There is a mechanical register which ensures that a known amount of compression, or, in certain cases, a known load, is applied on the bolts. In one case, where we were fairly close to the yield point, we measured the load on the bolt directly by measuring the extension of the bolt.

I cannot describe the gas seals used on this diffusion plant, but I can mention one or two seals which were used on other atomic energy applications, and particularly compressors which are used for reactor experiments, in which we circulate gas through part of the reactor ; this gas is active, and frequently we do not wish oil to be there. These are not vacuum seals, but they are seals which have to be gas-tight (the system does not run under vacuum). There is a good deal of information on these bearings. There was a paper by Mr. Ford, a member of this Institution, a year ago, and there has been an additional release of information recently.

I should like to emphasise the point which Mr. Burton made about welded joints. I feel very strongly that this is by far the safest way in a vacuum system. I strongly recommend that the first choice should always be a welded joint.

I was intrigued by the remark made about the poisoning of palladium. We have had a good deal of trouble. I was not aware that it was halogen which did the damage, but it fits in very well. We used carbon tetrachloride. I am not aware of this spectrum of leaks, and we shall have to look again at our results.

With regard to Mr. Livingstone's remarks about castings, I said in the paper that in my experience castings had not been satisfactory, but, of course, my experience is limited to a certain field. We have had a good deal of trouble with very large castings. It is possible to make castings which are vacuum-tight, but I should still be worried about the possibility of gas traps and porosity causing trouble. Where it is possible to seal castings with Araldite and epoxy-resins it is a very good solution. For our purposes Araldite was not satisfactory.

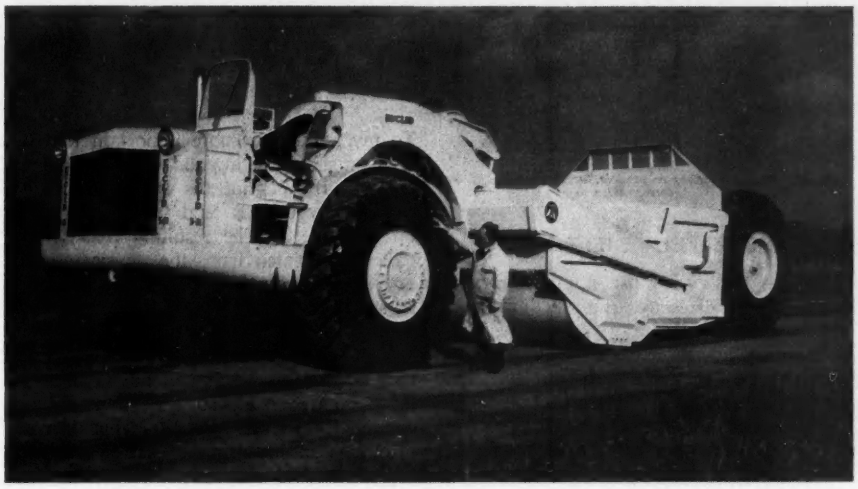
Some of the manufacturers in the early days considered a system to be tight if it was filled with water and nothing came out. I think that they did remarkably well in getting only 50 per cent rejections, and I can confirm the fact that very rapidly indeed the position improved, and now our failure rate is something like 2 per cent. I am not clear how much of this improvement is due to vacuum testing at the producers' works, but from our own experience in manufacturing we find that a rejection rate for standard components of 2 per cent is all that need be expected.

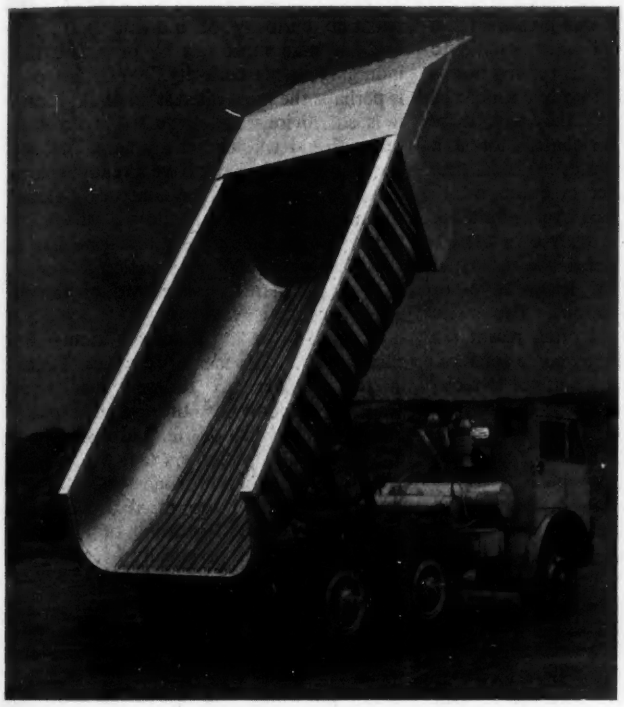
Reference was made to the argon arc welding of mild steel. I have to admit that most of our equipment is not made of mild steel ; we seem to go in for the exotic materials and to use niobium, tantalum and vanadium, and not so much mild steel, at any rate, in the first instance. We have certainly used argon arc welding on stainless steel and find it very satisfactory.

Finally, there is the very interesting problem of the vacuum testing of submarine equipment, to which I should like time to give some thought ; we have never had a problem of this kind. Leaks which change with pressure are known to us, but they are not common. If it is a question of several thousand feet head of water, however, such pressure-sensitive leaks would be quite common.

# Earth-Moving Equipment

The illustration on right shows the first unit of production of Euclid S.21 scrapers to leave the factory at Newhouse, Lanarkshire. These scrapers are the largest manufactured in Great Britain, with a load of 29 cubic yards when heaped to 1 : 1 slope and a gross weight of 56 tons. Up to 31 tons are carried upon the tractor axle, which is driven by a Cummins "Turbodiesel" of 320 h.p. This is a highly rated engine having six cylinders of 5¼in by 6in, developing a maximum b.m.e.p. of 173 lb per square inch and governed at 2100 r.p.m.



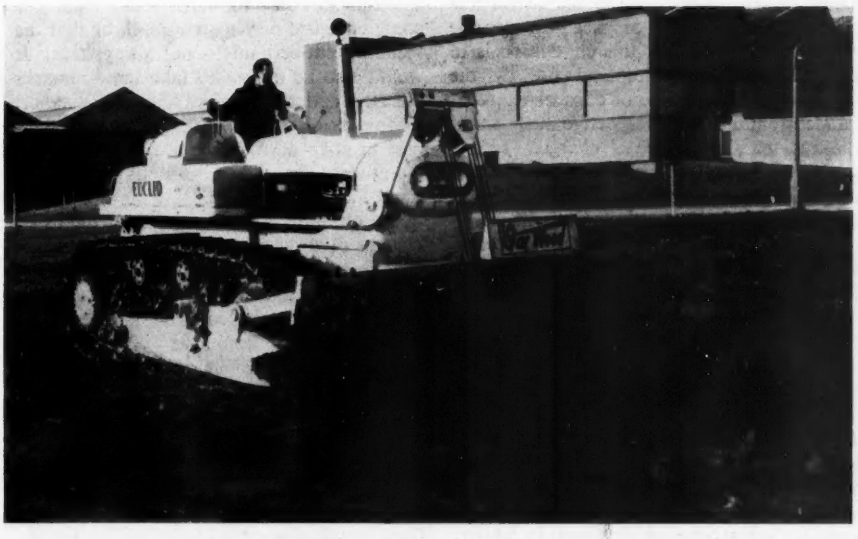


Transmission is by an Allison torque converter with a ratio at stall of 2·7 and a "Torqmatic" epicyclic gearbox giving four forward and two reverse ratios to an axle with initial and final reductions of 4·3 and 6·75 respectively. The planetary reduction gears are built inside the brake drums, on to which the 24·00×33 tubeless tyres of 24-ply rating are fitted. The scraper wheels are similarly tyred: braking is pneumatic, whereas other services are hydraulic. The steering is by two single-acting jacks and gives 180 deg. travel: the 40ft 9in long vehicle can turn in a space 36ft 4in wide. Three interchangeable rams operate the scraper, two being attached by levers to the bowl and one by cable to the apron: our illustration shows the apron down for spreading, over 2ft depth of spread being available. A fourth jack, a three-stage single-acting ram, drives the ejector. The maximum speed of the vehicles is 22 m.p.h.

There will be in production next year at the Euclid factory the C.6 tractor, the prototype of the British version of which is seen below in action. The United States product may be regarded as being one half of the TC-12 Twin Crawler (see page 628, November 2, 1956), having a General Motors two-stroke engine and a top speed of 8·3 m.p.h. Those built in Scotland will have a "Turbodiesel" and a maximum speed of 7·5 m.p.h. The power delivered by the engine is larger—235 h.p. instead of 194 h.p.—so that considerably greater tractive efforts will be encompassed. The engine is basically the same as that in the S.21, but with a much lower rating: it can be visualised that the work cycle of a tractor may be much more intensive than that of a scraper. The engines are assembled in the Cummins factory at Shotts, Lanarkshire.

The dumper shown on the left is a Foden demonstration vehicle fitted by G. E. Neville and Sons, Ltd., with a body constructed from Northern Aluminium extrusions. The body has a capacity of 10 cubic yards and weighs 2 tons 4 cwt: a steel body, we are advised, would weigh twice as much, so that 10 per cent more vehicles would be required to handle the same payload, and on this basis the aluminium body effects a saving in cost. The body is assembled by bolting to allow repair in the field. The main strength members are shallow U-shaped planks, reinforced externally with top hat sections bolted to the stiffening ribs of the planks.

The interior is lined with ¼in plate, and the bottom has impact strips which spread the loads longitudinally and protect the bolts. The sides are capped with double inverted channels of steel, the inner being attached to the body and carrying the outer on rubber bushes: the rails can be removed for straightening or renewal. The body is intended to handle quarried rock, and is described as ultra-heavy duty. There is a steel sub-frame, which rests upon the Metalastik rubber buffers visible on the chassis when the body is lowered: the tipping angle is 60 deg. The vehicle is powered by the six-cylinder Foden two-stroke engine; the three air cleaners seen are now superseded by a single 12in cleaner. The vehicle has Girling hydraulic power steering, and can be fitted with a hydraulically operated bulldozer blade. Braking is pneumatic by Bendix-Westinghouse equipment. There can clearly be distinguished on the covers of the final reduction gears the fittings for the withdrawal mechanisms: these can be moved with a tommy bar to give either 2 : 1 or direct drive between the half-shafts and the hubs



# LETTERS AND LITERATURE

## Letters to the Editor

*We do not hold ourselves responsible for the opinions of our correspondents.*)

### INSTITUTION MEETINGS

SIR,—I think it most appropriate and timely that in a leading editorial comment of a journal of your calibre plain words have been spoken about the frequently uninspiring character of the meetings of our technical institutions and societies (" Institution Meetings," THE ENGINEER, September 27, 1957, page 442). Many would no doubt wholeheartedly agree. But no one seems quite to know what to do. However, the above editorial comment to my mind gives one or two very good suggestions. I am elaborating upon those and adding one or two more, to help towards a better understanding of the problems involved, their source or origin, and their remedies. In the end I outline a novel kind of discussion meeting, much more congenial and useful, it is hoped, than the well-known varieties.

I am sure that the editorial comment of THE ENGINEER did not intend to convey the impression that the annoying phenomenon of bored audiences is caused by the technical character of the speeches delivered at these meetings. It is, of course, nothing of the kind, since the same trouble is well known with non-technical societies and institutions, in the field of pure sciences, education, and many others. Besides it is also, no doubt, well known that small and relatively informal lectures and discussion meetings (where there are no microphones or stenographers), such as for instance, university colloquia, are frequently boring to the audiences. The same often goes for full-dress large gatherings, such as, for instance, international congresses. Moreover, and this is a good point to keep in mind in this sort of earnest deliberation, the same goes for other countries, where it is quite possible that it arises even more acutely.

It is perhaps typical of our times that even men of quite high standing, who ought to know better, often put the blame for the uninspiring character of meetings on the audiences. A proof of this contention is to be found in the widespread use by the organisers of the device of cups of tea, &c., handed round to the prospective members of the audience, often free of charge. This is supposed to help overcome the alleged mental inertia of these persons. Worse still, a great many members of the audience, when confronted with inadequately prepared speeches, repeatedly fail to understand what is happening and conclude by imagining themselves, rather than the speakers, dull. If this sort of conditioning recurs it may have a permanent injurious effect. This is certainly not the intended social function and the professed end of holding the meetings of our learned societies and institutions. Note that this injurious effect can also be caused by too big a dose of good stuff at one sitting.

It is right to say that good public speakers are rare, because the art is difficult to master. To my mind it is more important that the speaker should be in good command of his subject. If he is not, his wishes or suppositions or hypotheses tend to become mixed up with facts. The resulting remarks are either dissociated from the physical reality or from the industrial situation with which it is supposed to deal, or are longwinded. Worst of all, there may be adroit speakers or writers who are unwise scientists or engineers; they make a great point of not saying anything controversial, so that they do not commit themselves. By displaying their art of talking and by using devices of speech or expression, they sometimes manage to gloss over many points of doubt. But these points are, more often than not, of real interest to other research workers or authors and to the industry. Therefore their well-presented and apparently elegant piece of work is likely to be in reality of little value. By trying not to commit themselves, so that no one should be able to challenge anything they say, these authors make it difficult for contributors to a discussion to come forward. Those who instinctively like the paper in question and do not notice the glossed-over points of interest, coming to relate their own experiences, cannot easily hang them on the paper and, consequently, offer longwinded or loosely associated contributions. Those who can see through the paper often resent the business and do not willingly come forward.

In this context it is perhaps useful to recall the following passage from page 555 of THE ENGINEER (" Lubrication and Wear," THE ENGINEER, October 4 and 18, 1957, page 485 and 555), " . . . there are possibly many members of the Institution of Mechanical Engineers who could have made a contribution to this (Lubrication and Wear) conference, but who did not in fact do so, . . . they (research departments) produce elegant investigations which deal with topics quite unrelated with the true industrial situation." It would be unwise to reject these strongly-worded anonymous views on some such formal ground that the first point is unrealistic because to allow many more speakers to come forward would make the conference last perhaps a month, or that the second point certainly is not always true. It would also be unwise to take these remarks literally, and then to imagine, for instance, that many of our industries have to do their best in spite of our technical and scientific literature. The author, no doubt, wished to plead the middle course.

The question is whether perhaps the usual manner of operation of our meetings somehow unintentionally helps these uninspired speechmakers and writers to come forward. It is of interest in this connection to recall the recent editorial comment of *The New Scientist* (" The Fight Against Scientific Bureaucracy," *The New Scientist*, October 24, 1957, page 7), written under the impact of the consternation here and in America caused by the first man-made earth's satellite, the Russian " Sputnik I." The material was largely drawn from W. H. Whyte's book, *The Organisation Man* (published in Britain by Jonathan Cape, 25s.). *The New Scientist* says : " This is a really important book, for in a beautifully clear and pungent style it analyses, explains and attacks a process more dangerous than any other to the democratic concept of living—namely, making the world safe for mediocrities, . . . big business is trying to stereotype the scientist into the accepted pattern of the firm in the same way as it has already 'harmonised' the executive class . . of 600,000 people engaged in scientific work (in the United States) no more than 5000 are free to pick their own problems, . . . parts of industry and Government bodies (in Britain) are drifting into the organisation attitude, . . . many of the most important technical developments have come about through the scientific curiosity of individuals, . . . the brilliant man must not be prevented from indulging in his curiosity." The last point is perhaps the most interesting of all, because it is so obvious and logical that no doubt many would wholeheartedly agree and support it. Indeed, many have already done so, including our great systematic logicians, Confucius and Christ, who also wished to follow the brilliant leader and give him all freedom of thought and action. For my part, rather than to concentrate on the rare great leader, I would allow everybody a little more breathing space for indulging in curiosity and other mental activities. Perhaps in this manner the brilliant man would gradually become a more frequent phenomenon in all walks of life, and this goes for our university professors as well as our unskilled labourers. One such mental activity, which all too often seems to be suppressed to the frustration of all, is the biological urge in practically everybody to commit little follies or miscalculations or mistakes. Indeed, this is how we all experiment and learn, almost automatically, under the spur of our biological need for self-expression and achievement, on the one hand, and under the check of our consciences punishing us quite automatically for all our mistakes. The point is that this personal mechanism is quite easily frustrated by too much punishment from others. A case to the point seems to be the following story about Rockefeller. One of his directors caused a heavy loss of money by some miscalculation. The loss was so heavy that many would feel he deserved to be scolded and fired. The wise Rockefeller knew better. He knew that the man must have already punished himself enough by being sorry. Also, his man had shown himself adroit on many earlier occasions, so that he did not want to frustrate or lose him. Rockefeller took the trouble to go and see the man as soon as he arrived and simply congratulated him and called him clever on the excuse of a trivial sum of money the man had retrieved, and added in a by-the-way fashion that the loss was anyway trivial in the long run and that many other of his employees had caused all manner of heavy losses.

Another way of causing mental strain

resulting in frustration and inefficiency is to ask a man to do two or more things at a time, particularly if some of the activities happen to be incompatible. This seems often to happen in the process of forming our research scientists and engineers, on the one hand, and our teachers and leaders, on the other. Our schools and colleges and universities and industries and research establishments seem to be in many cases equally unwilling and unintentional sufferers in this respect. The trouble is that everybody seems to try to educate or acquire the hypothetically universally able man, who, say, combines the qualities of a research scientist and of a teacher. To my mind we just cannot have it both ways. The true research type of mentality can be said to be one interested in the unwell-understood things, since it is to form hypotheses. Such a man mistrusts some of the old stuff (i.e. fundamentals) and actually fights against some of it. The remaining knowledge he treats with caution, and in effect tries to keep on pushing it down into his subconscious mind. In this fashion he uses what is already known, instinctively as it were, and so he has all his mental capacity for his hypotheses. But the true teacher seems to have the opposite type of mentality. He treats with caution the hypotheses, some of which appear to him only longwinded refinements of the well-seasoned regularities in which he takes real interest and which he calls fundamentals or laws. Now, a little reflection will show that the hypothetically universally able man, or the hybrid species of the two, can easily turn out to be the one who excels in trivialities.

In actual reality we often seem to be—unintentionally—moulding such hybrids. For instance, our university teachers or professors not infrequently are asked to lecture, do or supervise researches, and at the same time to be executives or administrators, consultants, councillors. But, according to the foregoing argument, it is unwise to ask them to do well the two first tasks simultaneously, let alone all the others. In industry the research scientist or engineer is usually asked to keep to his programme (i.e. not to form hypotheses), not to make mistakes (i.e. not to experiment), but to give right answers (i.e. to teach). In some such manner it can be understood that our industries are also unintentionally trying to form or acquire the hybrid species who excels in trivialities. Suppose now that a man trained in this fashion has submitted a paper for discussion at a meeting. If someone in the audience happens to discover some shortcoming in his paper he is likely to be horrified and to fight back by all manner of argument or device. Note that this sort of behaviour is much against the professed end of exchanging information at these meetings. Note also that it would be most appropriate for the teacher to put up a spirited fight when his fundamentals are put in doubt. It would seem, therefore, that the unco-operative attitude of the hybrid research scientist or engineer may be caused by confusing hypotheses with facts. However, an objection can be offered to the above argument, on the ground that even the hypothetically ideally trained research scientist or engineer cannot very well be asked not to fight back, but to take delight in the forthcoming valid suggestion. In fact, this is perhaps not an objection, but a clearly insoluble dilemma. In other words, the case seems to be that little, if anything, can be done to liven up these discussion meetings. Yet another apparently insoluble difficulty arises, namely, that the exchange of ideas at these meetings must rely on two somewhat longwinded impersonal activities, the collective listening and the multiple speech making.

The fundamental difficulties in the conduct of our ordinary discussion meetings seem to be capable of resolution by the following novel procedure, which could perhaps be given further study and then be encouraged in place of the usual procedure. To start with, let the author's paper be advertised perhaps a little more widely than usual, and then let it be distributed by post to all interested persons. Let these persons be asked to offer their contributions in writing, and let them be asked to include as much documented criticism as possible. Let, then, all the written contributions be handed to the author for an individual well-documented answer, answering minutely in turn all the points raised by each contributor. Let the whole, including the individual answers, be printed or duplicated and redistributed, so that each interested person, including all contributors, is given the full set of comments and answers to all. Simultaneously, let each interested person be given an invitation to attend a discussion meeting in, say, two weeks, so that all concerned have a sufficient time to study all ideas in detail. Much in accord with the suggestion offered in the editorial comment cited in the beginning, let the discussion meeting be purely conversational, without any speeches or stenographers, but let the mugs and tankards with their fill be fully provided, the reference library laid open, let also the film projecting facilities be there, as well as the facilities for writing, telephoning, and the like. Finally, let a good number of organisers be present, and let them make a real point of learning in good time who is who among the guests, and let them also make a real point of introducing appropriate men to one another all along. After the meeting, let the final written comments be asked from all, and again let all be invited to be as critical as possible and well documented. Finally, let the whole material be handed over to a highly skilled independent person for editing. Let this person be asked to cut out ineffectual passages and repetitions and the like, and to arrange all the like points under suitable headings. Let him be asked not to alter the tense except if incorrect grammatically, not to alter the style or tone or spirit of any contributions or of the original article. In the end, let the edited text be published as proceedings, within, say, three months from the arrival of the original manuscript.

It seems that the above proposal, if gradually adopted after further study, could also be made to go some way towards meeting F. H. Smith's plea (letter, "Institution Meetings," THE ENGINEER, October 4, 1957, page 492) that nowadays too many papers are read in too many places. Namely, as the next step in this direction, perhaps the ordinary discussion meetings could be altogether avoided. Also, the number of lecture meetings could perhaps be brought down to just a few really good ones. Finally, the meetings at which presidential addresses are read and the like could perhaps be turned into the conversational species on the lines indicated, say, by limiting the speeches to twenty minutes or so, and making these meetings much more of a social occasion than they now are.

W. LEWICKI

London, N.W.5, November 4, 1957.

### TECHNOLOGY AND WISDOM

SIR,—

We suggest Mr. Walker his Christmas devote
To revising his Latin, if tags he will quote,
And round his room paint, in a well-lettered mural,
"Even singular exceptions FLOREANT in the plural."

J. S. CASSON

University of Liverpool,
November 18, 1957.

## Book Review

**The Chemistry of Cement and Concrete.** Second edition. By F. M. LEA. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 70s.

THIS is a revised edition of the book first published in 1935 by Lea and Desch. It has been brought up to date and is written not only for the chemist, but also for the engineer and architect, who are concerned with the reliability of cement in use and the durability of concrete under various kinds of weathering and chemical attack. The raw materials, manufacture of cement, its internal structure and the process of setting and hardening, are comprehensively dealt with. Steam curing, shrinkage, setting time and strength are discussed. The properties of various kinds of special cements are described, and concretes made with many different kinds of aggregate or with entrained air. The durability of concrete and its resistance to chemical attack, particularly in tanks or frames, is well reviewed.

This is an important book, since the success of concrete as a structural material finally depends on its durability. There is a vast literature dealing with structural design, but the engineer and architect usually have little to refer to when problems of durability arise. At the Building Research Station, Dr. Lea has a unique opportunity of observing concrete structures which deteriorate through chemical attack or faults in the aggregate or in the cement used. With this background he has brought up to date a comprehensive textbook which has no rival in its purpose of presenting to the chemist and engineer an expert's knowledge of concrete from the chemical and physical aspects in manufacture, curing and weathering.

## Books Received

*The Economic and Social Consequences of Automation.* By F. Pollock. Basil Blackwell, 49, Broad Street, Oxford. Price 23s.

*Materials of Civil Engineering.* By J. P. M. Pannell. Hutchinson and Co. (Publishers), Ltd., 178-202, Great Portland Street, London, W.1. Price 21s.

*Radio Upkeep and Repairs.* Eighth edition. By Alfred T. Witts. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 15s.

*Engineering Metallurgy.* Part I. By Raymond A. Higgins. English Universities Press, Ltd., 102, Newgate Street, London, E.C.1. Price 25s.

*Coke-Burning Appliances Handbook.* Fifth edition. The Gas Council (Coke Department), 1, Grosvenor Place, London, S.W.1. Price 15s.

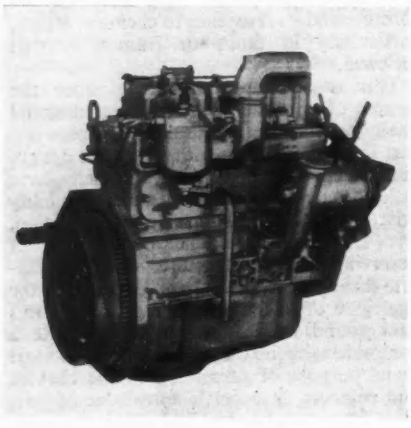
*Business Charts.* Fifth edition. By T. G. Rose. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 21s.

# Light Weight Diesel Engines

*Two oil engines recently introduced in this country are a four-cylinder, 99 cubic inch engine with a distributor pump and a high maximum speed, and a single-cylinder, loop scavenge, two-stroke, built largely in light alloy, with an automatic inlet valve. Both are finding their first application in agricultural plant.*

AN addition to the range of diesel engines manufactured by F. Perkins, Ltd., Peterborough, is a four-cylinder, 99 cubic inch model, the "Four 99." For agricultural purposes it has a rating of 35 b.h.p. at 3000 r.p.m. and a maximum torque of 64 lb-ft at 2000 r.p.m.; it weighs 456 lb. The construction of the engine, as the accompanying illustration shows, follows accepted principles, but a newly developed combustion chamber is incorporated.

The combustion chamber is formed principally by a recess, circular in section, in the cylinder head; the floor of the chamber is a shell-moulded insert of "Brimochrome." It can be discerned that the throat, which breaks through the floor on the side towards the engine centre, is short compared to its width, so that a projection at right-angles to the face of the head shows a small passage into the chamber. It is understood that on the early part of the compression stroke air enters the chamber in a predominantly vertical direction, and sets up a swirl in a direction clockwise on the drawing. Near the end of the compression stroke, and after injection has commenced, the air is closely constrained by the tapering groove machined in the head and by the top of the piston, and enters the chamber along the axis of the throat. Thus, the existing swirl is opposed and violent mixing may be envisaged. This chamber has a wide band of operating speeds

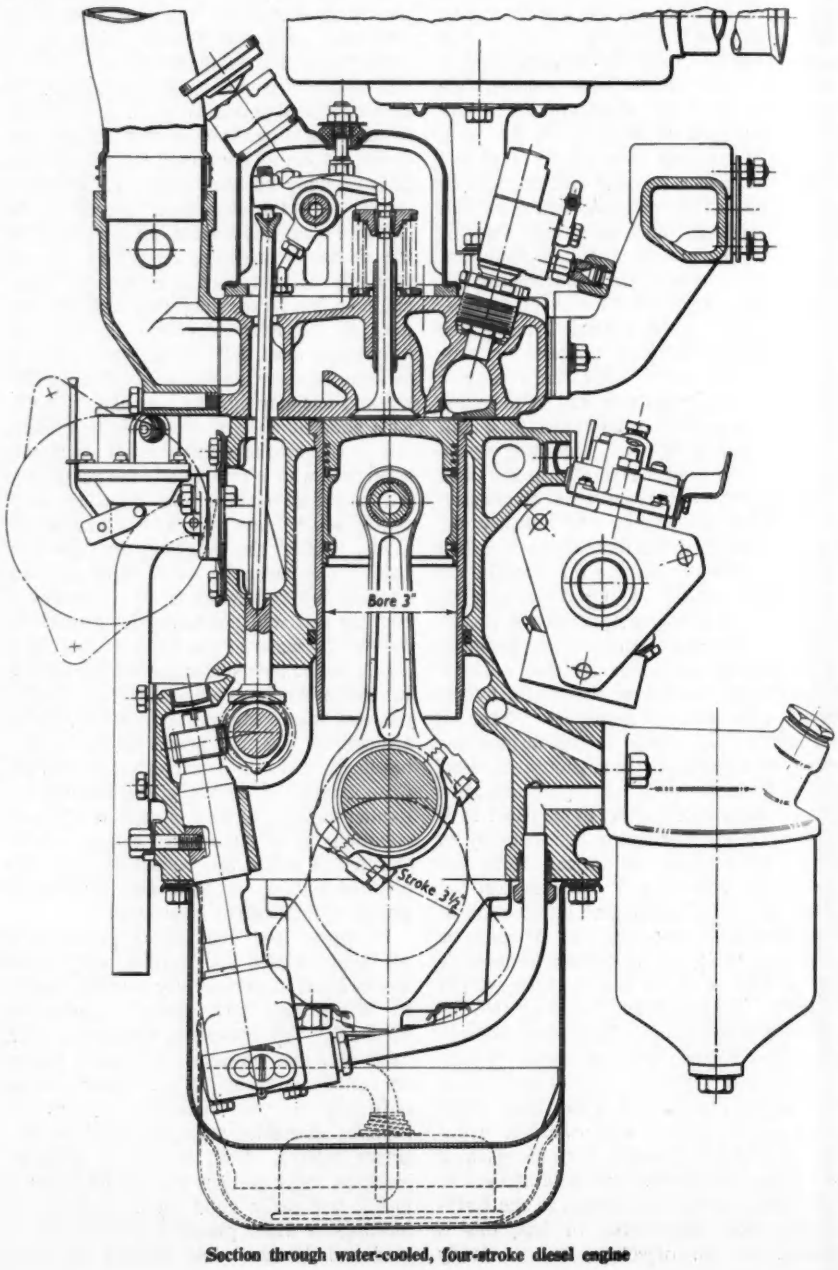


**A pre-production 99 cubic inch engine: the position of the injector drain rail is the same in production engines, but the dipstick will have a guide**

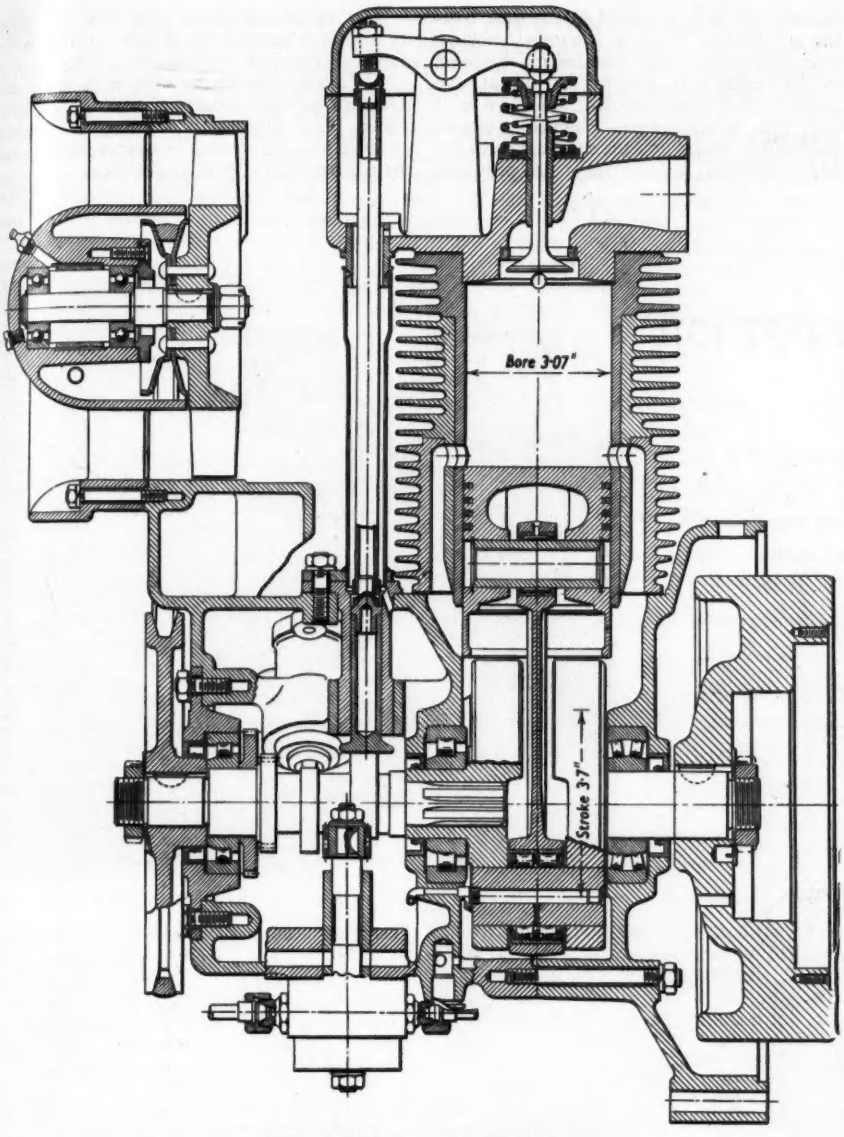
—in the 400 c.c. size the best consumption is close to constant between 1750 r.p.m. and 2500 r.p.m., and lies between 0·4 and 0·41 pints per brake horsepower hour—the brake mean effective pressure that can be attained, normally aspirated, is smoke limited at 120 lb per square inch. Cranking at 170 r.p.m. will cold start the engine down to 40 deg. Fah.; a "Thermostart" allows starts down to 2 deg. Fah. with a well-charged battery. (An ether starting aid may be specified for more severe conditions.)

The new chamber uses a pintle nozzle instead of the two-hole pattern of the "P" series engines. While the nozzle and working parts are standard C.A.V. components, the nozzle holder is special; it is secured by a large externally threaded nut, captive on the holder, which lifts it off its seat as it is unscrewed. The retaining nut, which has dogs engaging a special spanner, has a left-hand thread to avoid any tendency to loosen the nozzle on the holder. The fuel pump is a "D.P.A." model, with mechanical governing on the agricultural engines: however, pumps with variable timing and hydraulic governors have also been used in development work and have allowed power to be developed at over 4000 r.p.m. This form of pump was illustrated on page 374, September 14, 1956, but the cam form shown then, with the lift confined to a short arc, gave no control over unloading, which was particularly unfavourable on variable-timing pumps in which the interval between injection ending and delivery port closing was also varying, and was known to manifest itself in misfiring at low loads. The cam form used on this engine has a slight drop beyond its peak, so that unloading does occur, but this is followed by a dwell; thus, the plungers cannot move outwards before the delivery port closes and there is no tendency to empty the lines to the nozzles.

The compression ratio is held between 19 and 20 on production engines by selective assembly of pistons, whereas on the larger Perkins units the top face of every piston is machined after receipt from the supplier. Five rings, the topmost chrome-plated, are fitted from new and all are intended to be fully effective from the start. The cylinder head gasket is of steel, asbestos and copper; the steel is folded up round the flame edges and the copper down round the water edges. The top face of the wet liner is machined so that the gasket is nipped opposite the bottom face of the flange. The lower seal is to British Standard proportions, the rubber ring occupying 68 per cent of the groove volume, and no development effort was needed to secure a




**Section through water-cooled, four-stroke diesel engine**




Section through two-stroke, air-cooled engine

satisfactory seal. The block casting extends down to the crankshaft axis ; the end plates are made separate, at the rear to render the engine adaptable to various applications and at the front to reduce its cost.

The cylinder head has the inlet and exhaust ports on opposite sides ; the section shown here does not give a representative impression of the induction port, the volumetric efficiency being in fact so good that at 4000 r.p.m. the fuel efficiency continues to improve right up to full load. The head is secured by studs and nuts, which cannot be tightened with the rocker gear in place. The valve gear has been designed to use the minimum valve spring pressure in order to protect the tappet faces ; a parabolic acceleration characteristic with quietening ramps is used, and the gear is free from bounce up to 5000 r.p.m. The pressed steel rocker cover is heavily corrugated, seated on a thick rubberised cork gasket, and clamped by large rubber seals in order to quieten it.

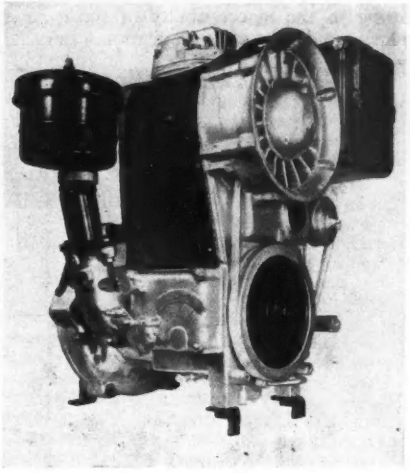
Timing is by gears, which are found cheaper than chain once the required degree of control over centre distances has been established. The idler is mounted on a stub shaft that can be moved in order to set the backlash in each mesh to about 0·002in ; this stub is fed with oil, which issues through holes in the hub of the idler to spray the gears. The half-speed wheels are identical and machined with three holes and three slots on a common pitch circle ; the camshaft gear is mounted on the holes and timed by meshing teeth, while the slots are used to give variation of pump timing in factory assembly only ; field timing of the pump, which has a master spline and can engage the gear in one attitude only, is by rotation of the complete pump on its three studs.

A skew gear on the camshaft drives a shaft running down to a self-priming Hobowen Eaton eccentric rotor pump, which in development engines only had a floating intake. The upper end of the shaft drives either a tachometer or the engine revolution counter which is used instead of a running time integrator. Another skew gear can be added to provide a light-duty drive for such purposes as windscreen wiping. The water pump is driven by the fan belt and provides a large coolant flow—33 g.p.m. at 3000 r.p.m. —to allow operation in high ambient temperatures ; a tapping point for hot water for cabin heaters is provided. Various sizes of starter motor are available, the smallest having a Bendix drive and the larger positive electric engagement.

Up to the present, about 100 engines have been turned out, and one has completed a 3000-hour run under full load at 3000 r.p.m. without deterioration in its performance. It is anticipated that production engines will have an overhaul life of the order of 10,000 hours. Complete performance characteristics are not yet available, but the agricultural rating quoted is guaranteed $\pm 2\frac{1}{2}$ per cent.

There are to be built in this country by Drayton Diesels, Ltd., West Drayton, Middlesex, two of the Stihl range of lightweight, loop-scavenge oil engines. Of this range some include a high proportion of iron castings because of the great cost of aluminium in Germany, but the engines to be built here under licence are two in which light alloy is used for many castings, with the result that the power-weight ratios, at or below 18·8 lb per brake horsepower, are claimed to be superlative. This excellence is due entirely to an efficient structure, the engine rating being by no means high with a maximum brake mean effective pressure of 63 lb per square inch and crankshaft speeds of 2000 r.p.m., or, in some cases, up to 2300 r.p.m. Engine lives of 3000 to 5000 hours with only routine servicing are anticipated.

The two engines are different only in cylinder bore, the type 34 being 3·07in by 3·7in (449 c.c.) and the type 35 3·23in by 3·7in (496 c.c.). The outputs are, on twelve-hour rating, 8 and 9 h.p. respectively at 2000 r.p.m., the maximum ratings being higher by 1 h.p. The construction of the engines can be followed in the illustration ; the cylinder liner and the topmost fins are cast in steel, and pressed into a separately cast light alloy jacket. The head is a light alloy casting with an inserted seat for the single exhaust valve. The twelve transfer ports are circular, and drilled at an angle to the radii on which they lie in order to impart a swirl to the charge. The small size of individual ports allows the rings, of which the top one alone is chrome-plated, to be unrestrained circumferentially.



The 8 h.p. engine with a 2-gallon mounted fuel tank : notice the visible level. Also to be seen are the half-speed shaft for hand starting, the external oil piping, the governor, and the strangler for starting

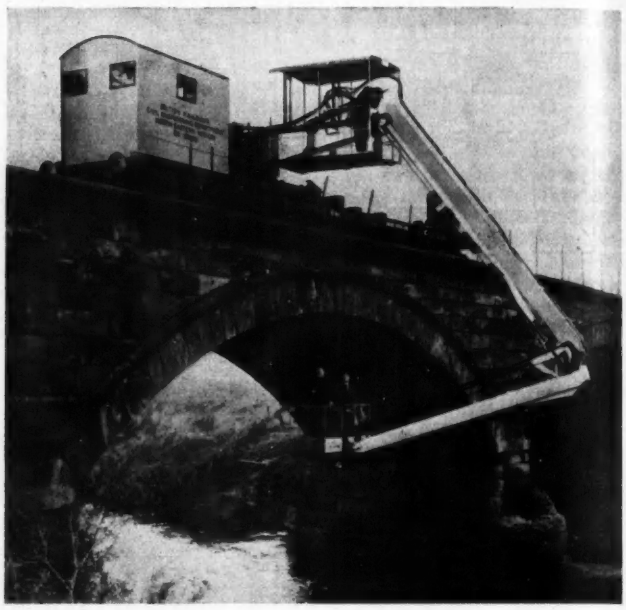
The crankshaft is built up in order to allow roller bearings to be used, since on a crankcase compression engine it is clearly unsafe to provide the lubricating oil delivery that would be necessary for plain bearings: consumption of H.D. oil is $2\frac{1}{2}$ per cent that of fuel. A forged steel connecting-rod has a needle roller small end bearing. The light alloy crankcase is emptied of oil by the pressure created within it during scavenging, and the oil is pumped from the cam chamber back to the oil tank ; this tank is cast in one with the cooling fan, thus securing some measure

of oil cooling. Admission of air to the crankcase is through an automatic inlet valve with a natural frequency much greater than the engine running speed ; air flow reaches a maximum at about 1700 r.p.m. with the maker's standard induction and exhaust systems. To reduce the cooling of the engine by excess air when starting, a butterfly valve is provided in the duct from the air cleaner. Starting is hand or electric, a decompressor being mounted on the cover of the rocker gear, and for starting at temperatures below 40 deg. Fah. and down to 11 deg. Fah. a self-igniting chemically treated wick is introduced into the combustion chamber : an excess fuel control is also provided.

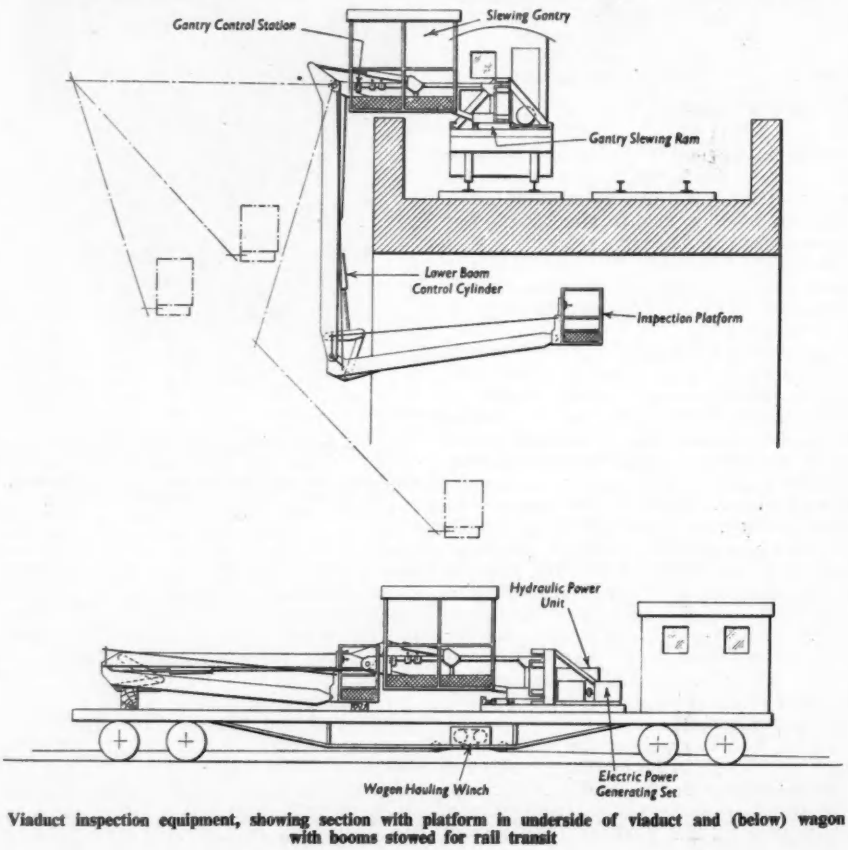
The engine is available with either variable or constant speed governing to within B.S. limits. Injection equipment is Bosch or C.A.V., and the engine will, as is usual in German practice, accept a wide variety of fuels. Consumption is between 0·47 and 0·49 pints per brake horsepower-hour at speeds over 1300 r.p.m. on full load.

# Railway Viaduct Inspection Equipment

*A mobile equipment which has been developed for use on the North Eastern Region of British Railways facilitates and speeds the work of inspecting the soffits and spandrels of high bridges and viaducts carrying railway tracks. This equipment, to be seen in use in the illustration on the right, consists of a bogie bolster wagon on which a pivoted gantry can be swung out to project over the side of the viaduct. Two hinged booms controlled through hydraulic rams are suspended from the gantry and support an inspection platform. This platform can be manœuvred to carry out inspections to a depth of 29ft below rail level and 15ft in from the side face of the viaduct.*



THE inspection of the undersides of viaducts and high bridges carrying railway tracks is frequently a matter of some difficulty owing to the inaccessibility of those parts which require the closest attention. In order to reduce to a minimum the time and trouble hitherto required for the erection of scaffolding or suspended staging to give access to the soffit, the civil engineering department of the North Eastern Region of British Railways has introduced a special rail-mounted inspection equipment. This equipment was developed to the requirements of Mr. Arthur Dean, chief civil engineer of the North Eastern Region, and designed in conjunction with Simon Engineering (Midlands), Ltd., and the Auto-Mower Engineering Company, Ltd.




**Viaduct inspection equipment, showing section with platform in underside of viaduct and (below) wagon with booms stowed for rail transit**

The general construction of the new unit and its method of use can seen in the drawing and photograph which we reproduce. It is mounted on a 52ft long bogie bolster wagon, which is 7ft 9in wide and 3ft 10½in from floor level to the rails. The inspection platform has a payload of 600 lb, and from it inspections of the undersides of viaducts or bridges can be carried out to a depth of 29ft below rail level and up to 15ft from the outside face of an arch. The three main parts of the equipment comprise an " A " frame with a slewing gantry, upper and lower boom members.

The " A " frame is rigidly bolted to a channel base on the wagon and has at its centre a hinge assembly carrying 2½in diameter bearings from which the slewing gantry is supported. This slewing gantry is of triangular cantilever frame construction, 12ft 6in long, and on each side of its main frame there is an operating platform 2ft wide, with a set of controls at the outer end of one platform. The gantry is slewed out to its operative position at 90 deg. to the centre line of the wagon by a 5in diameter hydraulic ram with a 36in stroke. This ram has two operating positions, which are selected in accordance to the required working side of the wagon. Its ram end is locked by a removable pin in the required side of the channel base frame unit to give the selected direction of slewing. When swung out the underside of the gantry clears a parapet wall 4ft 6in above rail level by 7in.

A 2½in diameter horizontal shaft at the outer end of the gantry provides the hinged mounting for the 21ft long upper boom to

which the 17ft long lower boom is also pivoted. These two booms are of rigid box section design and built up of welded light gauge steel sheet pressings. The upper boom can be swung downward from the horizontal position through 85 deg. by means of a 6in diameter, 36in stroke, hydraulic ram, which is mounted on top of the gantry frame. A similar hydraulic ram at the outer end of the upper boom is used to control the movements of the lower boom. When the upper boom is near its vertical setting down the side of a bridge, the lower boom can be moved from 30 deg. above to 60 deg. below horizontal.

The examiner's inspection platform at the end of the lower boom is 7ft long by 2ft 10in wide, and a simple parallelogram arrangement of tubular levelling rods, attached to the platform and separately fixed at the boom pivot points, ensures that the platform is always maintained in its horizontal position. Movements of the boom system can be controlled from the gantry platform by two double-acting hydraulic valve levers—one lever being used to serve the raising and lowering motions of each boom. These boom control valves are of four-way, open-centre, spool design, and they can be operated singly or together to give simultaneous or individual boom movements. Remote operating controls fitted on the inspection platform allow the occupants to control the movements of the booms within prescribed limits.

To provide the fullest possible range of inspection with the equipment, means are also incorporated in its design to move the wagon along the track under its own power with operator control. For this purpose a hydraulically driven bollard winch is fitted to the underframe of the rail wagon and its motor is remotely controlled from the operating platform. This winch comprises two parallel rows of gear-driven vee pulleys, driven through a dog clutch by a hydraulic motor. A ¾in diameter steel wire rope passes round these vee pulleys and is extended beyond each end of the equipment to anchors on the track in front and at the rear of the wagon. Using this winch, the wagon can be drawn along a viaduct or bridge at speeds of up to 40ft per minute when operated from the gantry control, or up to 20ft per minute from the remote platform control.

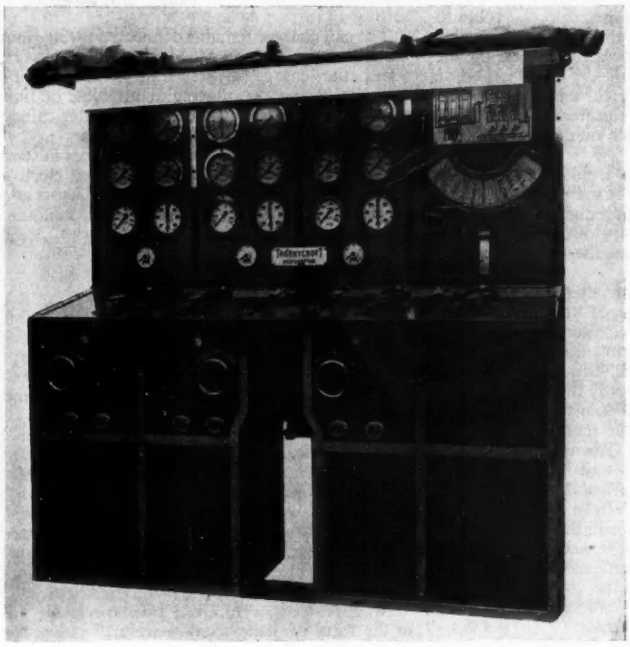
Hydraulic power for the equipment is supplied by a Petter diesel engine driving three hydraulic pumps. One of these pumps, delivering 2¼ gallons per minute at 1000 lb per square inch, provides power to the rams operating the slewing movements and the booms. The other two pumps, both delivering 5 gallons per minute at 1200 lb per square inch, provide power for the winch. A Hamworthy pressure-compensated control valve is fitted in the slewing and boom circuits. This valve regulates the amount of oil passing through to the control valves on the slewing gantry, surplus oil being by-passed back into the reservoir.

Facilities for covering the possibility of breakdown include the duplication of all hydraulic controls, and the fitting of "hydrolocs" on both boom circuits so that in the unlikely event of a hydraulic pipe failure the oil flow is locked and boom control is maintained. "Hydrolocs" fitted to the upper boom and lower boom control cylinders prevent oil leaving a cylinder until pressure is applied to the opposite end of the cylinder. Thus locked, the booms cannot move downwards under gravity. In the event of engine failure, a hand control can be fitted to operate the pump supplying power to the boom rams.

A 3kW d.c. generator driven by a Petter diesel engine provides power for lighting and for electric tools which may be used for breaking out defective masonry or brickwork. Two 300W floodlights, on universal swivel mountings, are fitted on the inspection platform. Spotlights fitted to each end of the rail wagon above the headstocks provide lighting along the length of the track as required, and working lights are also provided at the various control points. The 10ft long by 6ft 6in wide cab of the equipment is provided with a table and seats for the examination of plans. Communication between the cab and the men on the inspection platform is provided for by two field telephones.

## High-Pressure Fuel System in R.M.S. "Queen Mary"

FOLLOWING upon the installation of Denny-Brown stabilising equipment in the "Queen Elizabeth," the Cunard Steam Ship Company, Ltd., decided to equip the "Queen Mary" similarly. To accommodate the gear called for a considerable amount of rearrangement of the auxiliary machinery in the boiler-rooms, particularly the oil pumping and heating units, which had to be designed to occupy about one-third of the floor area required by the original units. The engineering departments of John I. Thornycroft and Co., Ltd., and the Cunard Company collaborated in the design, manufacture and installation of the new oil fuel system. Since a new system was necessary, the shipowners took the opportunity to raise the working pressure in the system to 450 lb per square inch, and to centralise combustion controls in the boiler-room in order to improve control of the boilers. The work was largely completed by the end of the ship's last winter overhaul in readiness for the work of installing the stabilisers during the liner's overhaul this coming winter.



**Boiler control panel**

*Main Particulars of System*

| | |
|---|---|
| Maximum working pressure of oil, pounds per square inch gauge | 450 |
| Maximum output of each pump, pounds per hour | 14,500 |
| Working temperature range of thermostat in oil fuel heater, degrees Fahrenheit | 240/300 |
| Steam pressure to heater, pounds per square inch gauge | 250 |
| Oil fuel heater relief valve setting, pounds per square inch gauge | 500 |

In each of the ship's four boiler-rooms has been fitted a triplex pumping and heating unit having a capacity such that two pumps and two heaters are sufficient to meet the demands of six Yarrow boilers working under normal service conditions, while the remaining pump and heater are available as a standby. Associated with each pump is a dual-suction filter through which the oil passes before entering, via a gate valve, a vertical Mirrlees "Imo" screw pattern displacement pump, fitted with a spring-loaded by-pass relief/control valve, designed to lift at 450 lb per square inch gauge. From each pump the oil is discharged through a screwdown non-return valve into a common main from which a branch pipe leads to a Thornycroft spring-loaded master pressure control valve mounted in the control panel. Excess oil is returned by the valve to the pump suction to provide pressure control. From the common main the oil fuel enters the three Thornycroft hairpin tube oil fuel heaters through individual inlet valves. Each heater is capable of raising 14,500 lb of oil per hour at a working pressure of 450 lb per square inch gauge through 200 deg. Fah. when supplied with steam at 225 lb per square inch gauge. Steam is supplied to the heater through Drayton thermostatically and hand-controlled slow opening valves, the bulb of the Drayton regulator being located in the oil heater discharge header. The heated oil enters the common outlet main through valves and passes to three self-cleaning plate pattern discharge strainers, each capable of dealing with the output of one pump and each having separate inlet and outlet valves. There is a common outlet to the boiler distribution system consisting of, in each boiler-room, three branch lines, each serving two boilers. At each boiler front there is a cast steel isolating valve, a "Stephens" quick closing low water valve, six burner valves and a circulating valve connecting with the existing hot oil return to the settling tanks.

A Thornycroft combustion control panel, illustrated herewith, is sited in each boiler-room and centralises oil and air controls to the burners. On the panel are dial gauges showing suction and discharge pressures for each pump, and others showing the inlet and outlet pressures of each discharge strainer, while a steam pressure gauge and an oil fuel outlet thermometer are provided for each heater. Also mounted on the panel are the boiler-room telegraph and answering bell, together with a boiler-room air pressure gauge, and the oil fuel master pressure control valve, while the electric controls for each of the three oil fuel pumps and the four existing fans are incorporated. The test pressure used for the oil fuel suction pipes was 100 lb per square inch gauge, while that used for the discharge pipes was 900 lb per square inch gauge.

STATIC PRESSURE PROBE.—In the August, 1957, issue of the *Journal of the Aeronautical Sciences*, there are presented, by Erik L. Mollo-Christensen, Marten T. Landahl, and John R. Martuccelli, the results of some experiments with a static pressure probe designed to be independent of Mach number. Slender body theory was applied to derive a fourth-degree polynomial for the profile of a solid of revolution, such that, at a certain distance from the nose, the pressure equals the static pressure in the stream far ahead. At that distance three holes were drilled at 120 deg. intervals, slender body theory showing that the mean pressure would be independent of yaw angle. A specimen of 0·120in diameter, with $^{1}/_{40}$in holes 0·50in from the nose, showed errors between +1½ and +3 per cent between Mach 1·3 and Mach 2; machining errors of 0·001in gave errors of 1 per cent. The tests were made in the M.I.T. 2in × 2½in tunnel.

# Automatic Trunk Telephones

## GROUP ROUTING AND CHARGING EQUIPMENT "GRACE"

THE reductions in telephone call charges which the Postmaster-General recently announced, to take effect from January 1, will result from a new system of routing, in which exchanges will be grouped and all exchanges in a group will have the same charges. It is stated that this simplified system will prepare the way for subsequent automation of the trunk service, which will result in big economies in operation and administration.

For trunk dialling by subscribers, a system of national numbers will be required. New equipment has been developed by the G.P.O. to handle most of the automatic operations involved in this innovation; it is known as "GRACE" (group routing and charging equipment). The group routing and charging equipment does automatically what the trunk operator now does manually in setting up a call. It notes the number dialled by the caller and decides the correct route and charge rate. It then selects a route to the required exchange, and when the called subscriber answers it records the charge on the caller's exchange meter.

The equipment has three main parts—call chargers, registers and translators; their numbers vary with the number of calls to be dealt with.

To make an automatic trunk call the caller dials the national number of the person to whom he wishes to speak. The first digit of all national numbers is "0" and receipt of this digit by the exchange equipment causes the call to be connected to a call charger.

The call charger associates itself with a register and the remaining digits of the number are received and stored in the register, which forms a memory for this information during setting up of the call. The first one, two or three digits received by the register identify the distant group. It is the function of the translator to inspect these digits and deduce from them the route and charge rate for the call. The translator is the "brain" of the system and incorporates a permanent memory giving details of the routes and charge rates for calls from the originating exchange to all other groups in the country.

The digits stored in the register are referred to the translator which examines them, identifies the exchange code, selects the appropriate route and charge rate for the call and passes this information back to the register.

The information is in the form of a charging rate digit and from one to five routing digits.

**Fig. 1—The electronic equipment for "Grace" is mounted in racks 10ft 6in by 4ft 6in. A register rack is on the left and a translator rack on the right**

To avoid having to provide storage capacity in the register for all these digits at once, it is arranged that they are passed to the register one at a time as required. The register uses the digit supplied by the translator to further the setting up of the call and then makes a fresh demand for another digit, indicating to the translator which one is required. The time taken by a register to use a digit is far greater than the time the translator takes to supply it. The translator is therefore freed between demands for use by any other register requiring its services.

The first digit returned to the register from the translator is used to select the appropriate charging rate in the call charger. Subsequent digits are used by the register to operate switches in the originating and distant exchanges to complete the connection. When the connection has been completed the register is released and made available for use with other call chargers in setting up further calls.

The call charger remains connected throughout the call and when the called subscriber answers, levies the charge by operating the caller's exchange meter periodically at intervals of time depending on the distance between the calling and called subscribers' charging groups.

The equipment has been developed in two different forms, one using conventional electro-mechanical components—mainly uniselectors and relays—and the other using electronic techniques. The electronic version will be employed in the first installation at Bristol and the following description refers to this kind of equipment.

### ELECTRONIC "GRACE"

The electronic equipment is based on the use of cold cathode tubes. The Post Office have been experimenting with the use of these tubes in telephone equipment for several years and experience has shown that very reliable service can be obtained. The "voltage transfer" method of using cold cathode tubes has been adopted. With this method the output potential from one tube is sufficient to strike another tube, the potential being controlled by rectifier gates. Rectifier gating permits combinations of tubes to control the striking of another tube without mutual interference. Miniature selenium rectifiers are used to form the gates.

*Register.*—Digits received by the register are in the form of dial pulses—a train of pulses for each digit. These pulses are counted on the incoming counter, which is a chain of cold cathode tubes. When a pulse train ceases the number of pulses counted is stored on five tubes in "two out of five" code by striking the appropriate two tubes. The incoming counter is then reset ready to count the next digit and a second counting chain is stepped to keep check of the number of digits received. Up to nine digits may be received and each is stored on a separate group of five tubes, requiring forty-five tubes for digit storage. Digits to be transmitted by the register are received from the translator and stored temporarily on the counting chain tubes of the outgoing counter. The register then generates pulses—like those generated by a dial—and as each pulse is transmitted it is counted by the outgoing counter until the correct number has been transmitted. The register then receives the next digit to be transmitted from the translator, and as soon as the "inter train pause" switching period has expired this digit is transmitted.

*Translator.*—The electronic translator can deal with a register in a few milliseconds. This high speed of operation permits the translator to be connected to a register at regular intervals, whether the register requires the translator or not. The translator acts as a common control. Each time it is connected to a register it can decide what action, if any, is required. In this common control arrangement a simple design of register is suitable since the register is merely a slave acting on instructions from the translator. Registers are connected in sequence and up to forty may be controlled by one translator, each register being connected once every two-thirds of a second.

Since a translator is common to as many as forty registers a faulty translator could seriously disrupt service to subscribers. It is arranged, therefore, that any maloperation is detected by check circuits and causes a standby translator to take over service automatically. Thus, in the rare event of a translator developing a fault only one call can be affected.

*Construction.*—The equipment is mounted on standard sized telephone racks approximately 10ft 6in high and 4ft 6in wide (Fig. 1). Racks for the electronic equipment are box section and divided into cubicles catering for twenty registers per rack or three translators per rack. Equipment in a cubicle is mounted on "leaves" which are hinged together at the rear to form a "book" (Fig. 2). Cold cathode tubes are mounted

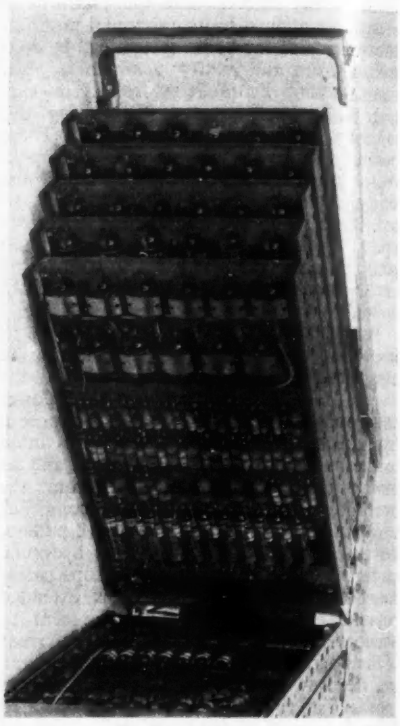


**Fig. 2—The cold cathode tubes and other components of an electronic register are mounted on "leaves" hinged at the back to form a "book" as shown here**

at the front of the "leaves," so that their glow can be observed through the red-tinted front cover. Access to the equipment for fault location can be obtained by opening the front cover and parting the "leaves" at any desired position, free space at either side permitting the "leaves" to be opened to a wide angle. If work has to be carried out on the equipment it may be unplugged and removed from the rack.

*Initial Installation.*—The initial installation at Bristol will consist of sixty-six registers and three translators. Two of the translators will be in service normally, the third acting as standby for either of the other two. This equipment can handle about 6000 calls per hour, and can establish connection to the called subscriber within a few seconds of completion of dialling.

The system has been devised by Post Office engineers and the equipment for the initial installation has been designed and developed in co-operation with The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2.

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TRACKING THE EARTH SATELLITE.—A paper on "The Tracking of the Russian Earth Satellite" will be presented by D. L. Cooper Jones at a meeting of the London Graduates and Students Section of the Institution of Electrical Engineers, Savoy Place, London W.C.2, at 6.30 p.m. on Wednesday, November 27.

# 800 h.p. Diesel-Electric Locomotive

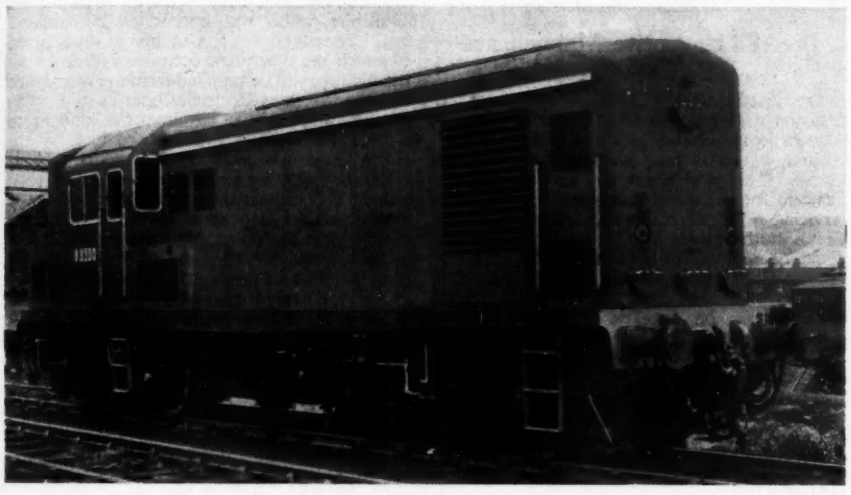
THE first of the ten type 1 (formerly type A) 800 h.p. $B_0$-$B_0$ diesel-electric locomotives ordered from the British Thomson-Houston Company, Ltd., by the British Transport Commission was officially handed over on Monday last, November 18. The leading particulars of these locomotives, which are intended for main line freight duty, are given in the table below.

*Particulars of* 800 *h.p. Diesel-Electric Locomotive*

| | |
|---|---|
| Weight in working order | 68 tons |
| Length over buffers | 42ft |
| Bogie wheelbase | 8ft 6in |
| Bogie centres | 22ft 6in |
| Maximum speed | 60 m.p.h. |
| Maximum tractive effort at starting | 37,500 lb |
| Continuous tractive effort | 20,000 lb at 10·5 m.p.h. |
| Engine | 800 b.h.p. at 1250 r.p.m. |
| Generator rating | 500kW, 690/337V, 720/1320A |

They will all be allocated to the Devons Road motive power depot in the London Midland Region and will work freight trains between Poplar, Temple Mills, Acton and Willesden.

The whole of the electrical equipment for the locomotives is being supplied by the British Thomson-Houston Company, Ltd., as the main contractor, the superstructures and bogies being made by the Clayton Equipment Company, Ltd., the underframes by the Yorkshire Engine Company, Ltd., and the engines by Davey Paxman, Ltd. As can be seen from the accompanying illustration of the first of these locomotives, they are of generally conventional design.



**$B_0$-$B_0$ 800 h.p. diesel-electric locomotive for freight service on the London Midland Region of British Railways**

The rigid underframe of deep channel longitudinal members with channel solebars carries a superstructure of mild steel plating on an angle framework. A single intermediate driver's cab, provided between the main engine and radiator compartments and a control gear housing, has two driving positions, one for each direction of travel.

Horizontal adjustable louvres at each side of the locomotive control admission of air to the radiators, and a radiator fan mounted horizontally below the roof of the housing, is driven by shafting from the engine through a bevel gearbox. To give adequate access for inspection and maintenance, full-depth hinged doors are provided on each side of the engine and generator housing, and hatchways are fitted in the roof over the engine. Air filters, protected by fixed horizontal guard rails, are provided in each side of the locomotive to serve the motor blowers, the main generator and the compressor. An angle section continuously welded to the upper surface of the footplate around the engine forms a sump and from this sump any leakage of oil may be drawn off from one side of the locomotive.

Each of the bogies has solebars of deep channel section spaced by headstocks and crossbearers and jointed by riveting, the joints being reinforced by gusset plates. A swing bolster has a double-elliptic spring at each end. The cast steel axleboxes are fitted with SKF single-row, self-aligning roller bearings, and these axle boxes, like the horn guides, are provided with manganese-steel wearing plates. Underslung equalising beams centralise the load on the axleboxes and reduce friction on the horn guides to a minimum. The main suspension is by helical springs on these equalising beams and Woodhead-Monroe hydraulic shock absorbers are fitted. The bogie centre pivot and side bearers are of cast steel and a bronze liner plate is fitted between top and bottom pivot plates.

The two traction motors on each bogie drive through single reduction gearing, and the four traction motors of the locomotive are connected in parallel across the main generator with one step of motor field weakening. The link design nose suspension of these motors employs "Silentbloc" bushes at each end. A further link with similar bushes connected horizontally between the motor frame and the side of the bogie controls lateral movement of the motor irrespective of side movement of the axle, thus reducing flange wear and improving the riding of the locomotives. The gearwheels are of resilient design and consist of a hub and toothed rim connected through rubber bushes which cushion mechanical shocks due to accelerating forces and track irregularities.

The Paxman sixteen-cylinder oil engine has a traction rating of 1000 b.h.p. at 1250 r.p.m., but for this application has its fuel bar set to develop 800 b.h.p. at 1250 r.p.m., with a brake mean effective pressure of 106·5 lb per square inch and a mean piston speed of 1615ft per minute. It is coupled to a generator unit which is mounted on an extension of the underbed and comprises a main generator, a differential exciter and an auxiliary generator. The main 500kW generator is a single-bearing, six-pole, separately-excited, self-ventilated machine. The auxiliary generator is an eight-pole, separately-excited, constant-voltage machine rated at 40kW, 110V, 625/1250 r.p.m. Its armature is mounted on the main generator shaft and its frame is an extension of that of the main generator. The exciter, which is mounted above the auxiliary generator and belt-driven from the main generator shaft, is a four-pole machine with self- and differential-series excitation.

Engine speed is controlled by compression of the governor control spring by a pneumatic cylinder, and variation of air pressure in this cylinder is effected by a control valve in the driver's control handle. The generator loading is automatically varied so that it agrees with the predetermined engine output at any particular engine speed.

The control gear is arranged into two sections on the locomotive—the control frame and the cab control equipment. The control frame is mounted in a dust-tight compartment behind the driver's cab and is remote from any possibility of contamination from the diesel engine. On this control frame are located all contactors, relays and switch devices. Separate contactors are provided in each motor circuit, and a butt contact reverser is electro-pneumatically operated. Access to this control gear is conveniently obtained by means of doors at either side of the locomotive. The control equipment in the cab comprises two master controllers and instrument panels, one at each driving position, together with alarm identification panel, engine instrument panel, lighting switch boxes and fire alarm unit.

A lead acid battery for engine starting duty is maintained charged by the 110V auxiliary generator controlled by a Brown Boveri automatic voltage regulator. A Westinghouse compressor, providing for the air brakes and other air services, is controlled by an automatic governor. Two Westinghouse exhausters are fitted for servicing the vacuum train brakes. These exhausters normally run at slow speed to maintain vacuum, but they are accelerated to obtain a quick release of the brakes when a trigger on the driver's vacuum brake valve is operated. Two blowers which supply cooling air to the traction motors run continuously whilst the engine is operating, and relays in the motor circuits give warning if either motor fails.

## Creep Tests for Materials on Gas-Cooled Reactors

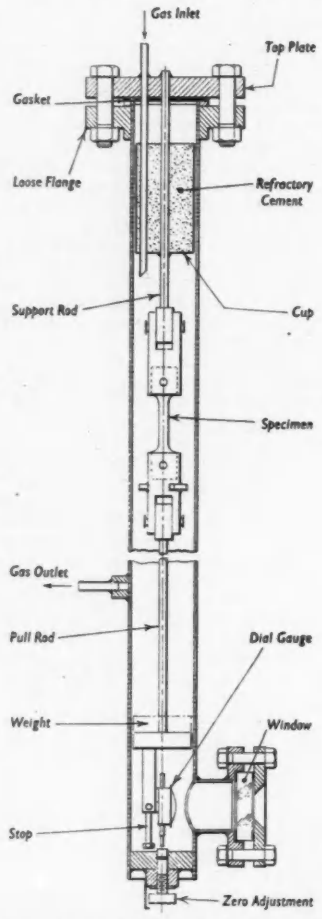
WE learn that new research equipment, designed to provide preliminary creep and stress-rupture data on metals and alloys in gaseous atmospheres at high temperatures and pressures, has recently been installed in the materials research laboratory of the G.E.C. Atomic Energy Division at Erith, Kent. Twelve creep-test units are reported to have already done valuable basic work on the properties of magnesium alloys (for fuel element cans) in carbon dioxide atmospheres. The equipment has been installed to provide facilities beyond those of normal metallurgical laboratories: the urgency of the nuclear power programme demands a much greater pace than usual.

Machines for creep tests in air are standard laboratory equipment, and it is comparatively easy to adapt them for other atmospheres by enclosing the test piece in a gas-tight vessel, the pull-rod passing through a gas seal. This arrangement is used only at atmospheric pressure, however, and while the results obtained are valuable, it is desirable to investigate the effects of gas pressures such as prevail in a reactor circuit. It is not claimed that the units at Erith can be used for a complete investigation of creeping materials under reactor operating conditions. Within the time available, however, they are believed to provide an efficient means of obtaining, very rapidly, a broad assessment of materials for reactor service. More detailed investigation can then be undertaken on materials which pass this preliminary test. Within these limits, the equipment is stated to have proved capable of consistent and reproducible results.

As shown in the illustration overleaf, the specimen, the whole of the stressing apparatus, and the associated extensometer, are all enclosed in a vertical cylindrical pressure vessel enveloped along part of its length by an electric furnace. The pressure vessel, which is of stainless steel $\frac{1}{16}$in thick, is approximately 5ft long and has an internal diameter of 4in. At its open upper end it is provided with a machined facing flange. The top plate is bolted down to a loose flange slipped over the vessel, a gasket ensuring gas-tightness.

The upper end of the support rod, from which the specimen is suspended, is welded to the centre of the top plate, while its lower end carries

a pivoted coupling similar to one at the top of the pull-rod. Alternative couplings are available so that specimens of either rectangular or circular cross-section can be used. A cylindrical cup, which is a loose fit in the pressure vessel, is welded to the support rod between the top plate and the coupling, and is filled with refractory cement to provide heat insulation. The loading weights are mounted on a plate welded to the lower end of the pull-rod. To the underside of this plate is attached a bracket carrying a dial gauge, whose operating head rests on the end of a bolt passing through a rubber gas seal in the bottom plate of the pressure vessel. The bolt serves as a zero-setting device for the gauge. The gauge reading can be observed through a pressure- and heat-resistant glass window mounted between soft rubber




**Cross-section through pressure vessel of a creep tester**

gaskets in a tube welded into the side of the pressure vessel. A stop is provided beneath the gauge mounting; this is to prevent excessive travel of the pull-rod, which might damage the gauge on rupture of the specimen.

Gas is admitted to the pressure vessel through a tube of ¼in internal diameter passing downwards through the top plate and the refractory cement plug. A gas outlet tube of the same diameter is welded into the side of the vessel below the operating section.

The 4kW electric furnace is built in two sections and can be split by unbolting two vertical clamping plates, thus allowing the pressure vessel to be removed. The heating elements are carried in slots in the inner faces of insulating bricks which are assembled in a hexagon around the pressure vessel; the space between the bricks and the furnace casing is filled with refractory cement. The vertical wound length of the elements is 21in, which is reported to give a satisfactory temperature distribution in the region of the specimen. The two heating elements, one in each half of the furnace, are connected in parallel to a 240V, single-phase, 50 cycle supply, the leads being brought out through the element bricks to terminal blocks mounted in ventilated chambers built round the top of the furnace casing. Connected in the supply circuit are a main contactor, housed in a cubicle mounted on the furnace casing, and a controller for coarse regulation of the furnace supply, particularly during the warming-up period.

Two thermocouples are employed. One is mounted directly on the specimen and is usually connected to a recording instrument, its leads being taken upwards through the gas inlet tube, from which they issue through a gas seal. The second is mounted next to the furnace winding and is connected to a temperature controller housed in a louvre-ventilated casing built into one of the two terminal chambers. With this arrangement, it is stated, extremely sensitive regulation of specimen temperature has been achieved.

When the stressing apparatus (with the test piece in position) has been lowered into the pressure vessel, the top plate is sealed down. The vessel is then thoroughly flushed with the gas being used for the test before being brought up to pressure. The supply to the furnace is adjusted to raise the temperature of the specimen rapidly to the required value, and it is then maintained at this level by the temperature controller. When stability has been established, extensometer readings are taken at suitable intervals, the results being plotted as percentage creep against time. The total duration of the test varies according to the particular requirements, but is normally between 150 and 1500 hours.

## Diesel Locomotive Maintenance Depot

THE accompanying illustration shows the first new motive power department diesel maintenance depot to be built for the London Midland Region, which is now nearing completion at Crewe. This new depot will provide modern facilities for the maintenance, examination and servicing of diesel equipment allocated to the Crewe motive power district, which will include diesel locomotives for both main line and shunting duties and multiple-unit diesel trains. The depot will also be a concentration point for maintenance work on diesel units from adjoining districts.

The depot contains five through roads, 270ft long and five short roads, 80ft long. The shed is 141ft wide and is equipped with all the machinery and power tools necessary for the running maintenance of diesel locomotives. All roads inside the shed are provided with inspection pits fitted with fluorescent lighting for the whole of their length, and there is sufficient pit capacity for work to be carried out on seventeen locomotives at any one time. Work above rail level is facilitated by light movable platforms for use by repair staff and the working area is illuminated by powerful overhead lighting. Pits on all outside roads at the north (incoming) end of the shed will be used, among other things, for washing down and cleaning the units before they enter the depot.

Three short roads inside the south end of the shed will be used for the testing of main line diesel locomotives. The other two short roads at the north end of the shed are for the maintenance of the diesel shunting locomotives which have been based at Crewe South for several years, and have hitherto been maintained at the steam depot. This part of the depot is already in use.

**New diesel locomotive maintenance depot at Crewe**

## Glass Factory at St. Asaph

CONSIDERABLE developments have taken place since Chance Brothers, Ltd., commenced the manufacture of optical glass for instruments at Smethwick, Birmingham. Since 1939 a major portion of the glass for spectacles has been produced in rolled plate form by Pilkington Brothers, Ltd., at St. Helens, Lancashire. Some time ago it was decided to integrate the production of these allied products by installing a new continuous process and work was begun in 1956 on the building of a new factory, with the name Chance-Pilkington Optical Works, at St. Asaph, Flintshire, which was opened on November 8 last. The site chosen has an area of thirty acres, of which the new plant occupies five, and electrical power will be supplied from the Merseyside and North Wales Electricity Board's grid, while gas, of which initial requirements amount to 5,000,000 cubic feet, will be provided by the North Wales gas grid. Three production units will be in use by the end of this year and the total output, it is estimated, will be about 60,000,000 optical blanks per annum. So far, mainly optical glass for ophthalmic use has been produced, and it is expected that four tints of Crookes glass will also be produced, while next year the factory will begin manufacture of large shielding windows for radiation protection in the nuclear energy field.

The St. Helens factory will continue to manufacture optical glass, including the casting of large discs up to 50in diameter, and the Smethwick works will continue to manufacture ophthalmic glass by re-pressing glass made at St. Asaph. The works at St. Asaph will be the administrative centre.

# Power Supply Stand-by

A DIESEL-ELECTRIC unit known as "RACO" (" rapid automatic change-over ") has been developed by J. and H. McLaren, Ltd., of Leeds, for controlling generating sets in unmanned repeater stations, and to act as a safeguard against a reduction or complete failure in electric power supply. Our illustration shows a control unit undergoing tests. The applications of " RACO " are divided into two main kinds. First, to ensure that, in the event of power failure, the minimum delay occurs before the equipment takes over the load, and second, to ensure that there is no break in the continuity of full electric power supply.

*Short Break.*—For telecommunications the control gear is designed so that any break in current supply is either less than 3 milliseconds or more than 10 seconds. The new control gear can transfer a load from one power source to another with an interruption adjustable down to 2 milliseconds. Generating sets employing this system may be used either as a direct source of power or, where a no-break power supply is essential, as the source of an energy storage system. In either application the control gear is the same and arranged for assembling on a unit system. The basic unit is called a " RACO " control panel. This is a dustproof, wall-mounting cubicle containing all the contactors and relays necessary to start and stop the generating set when given the necessary impulse from an external source. The cubicle also contains fault-detecting and signalling apparatus for its particular generating set. If the set is on mains standby duty, the " RACO " control panel is energised from a change-over panel which contains the mains failure detector relays, load transfer contactors, trickle charger, instruments, manual and automatic switches, isolating switch and provision for supervisory and remote radio control.

Where no mains are available, dual or triple generating sets are installed, each with its own control panel. Two sets are arranged to operate on a seventy-two-hour cycle basis. In triple installations a pair of sets normally shares the duty cycle while the third set acts as standby. Under fault conditions on either of the duty sets, the operating sequence is automatically diverted to the third set. The cyclic time switch, change-over contactors, trickle charger, instruments, manual, automatic switches, isolating switches and provision for remote radio control are all accommodated in a separate dustproof wall-mounting unit called a timer cubicle.

*Mains Stations.*—Under normal conditions, the mains supply is connected to the load and the set is on standby duty. Sets above 6kW capacity are fitted with a lubricating oil priming pump which is arranged to operate on a time cycle of approximately three minutes every eight hours. The pump is electrically driven and is isolated from the mains when the set is running. Upon failure or 6 per cent reduction in the mains voltage for a period of three seconds, the set automatically starts and supplies the load. The supply contactor is of the change-over pattern, fitted with mechanical and electrical interlocks. When the mains are restored, a process timer is connected in the circuit with a cycle adjustable up to thirty minutes. At the end of the timer-operated cycle the load will be reconnected to the mains with an interruption of current supply of approximately 10 milliseconds. If at any time during the cycle the mains fail and are again restored, the timer automatically resets to its full duration, thus acting as a reference for the regulation and definite stability of the mains supply source. After the load has been transferred to the mains, the engine runs for a cooling-off period of five minutes before shutting down and resetting itself automatically for the next start on demand.

**Testing control gear for diesel-electric generating sets with rapid automatic change-over**

*No-Mains Stations.*—Under normal conditions, one of the two sets is supplying the load while the other is acting as a standby. After a period of 71·75 hours, a synchronous driven timer will start the second set and at seventy-two hours a high-speed changeover is instigated, the break being adjustable between 2 and 25 milliseconds. The second set now supplies the load and runs for a further period of approximately seventy-two hours before starting the first set again, which warms up for fifteen minutes before another change-over is effected.

A two-position switch is fitted on each control panel to provide for local operation tests. In the " auto " position the set is controlled by the timer panel or the change-over panel ; in the " local " position the set may be hand cranked or may be controlled by stop and start switches located on the face of the cubicle. In the " local " position it is possible to run the set up to speed for a full start-run operational test sequence without energising the main contactor. The control gear is arranged so that a remote starting impulse can be transmitted by radio to start the standby set and enable it to take over the load for a period of approximately thirty minutes. This feature is of particular value where it is known that the mains supply is to be cut off at a specified time.

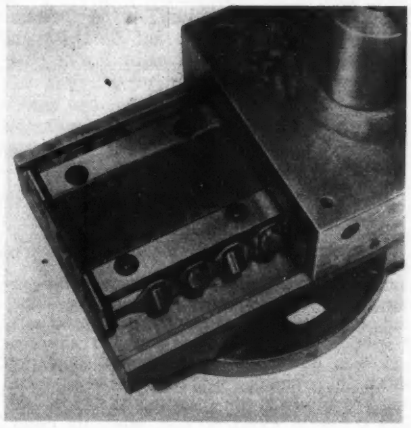
Petter or Petter-McLaren air-cooled diesel engines are used and will operate over a wide range of temperatures, so that the standard set may be sent anywhere from the Poles to the Equator without alteration. Since the engines may be required to run for periods up to 1000 hours without any attention, grease points are eliminated and any grease packed bearings are capable of operating for this period without repacking. Air, fuel and lubricating oil filters must be used and, in most instances, duplicate filters are provided which permit the cleaning of one filter whilst the other is in operation, so that the engine need not be shut down even during the maintenance period. It is necessary to provide also for a device to top-up the sump level, and this is accomplished by a spring-mounted supplementary lubricating oil tank.

*No-Break.*—The most economical method of converting the " RACO " to a no-break system is by using a continuity unit. This consists of a low-slip induction motor, heavy flywheel anp alternator, all mounted on a common bedplate. The alternator is driven through the flywheel and forms the permanent source of supply to the radio equipment and essential services. The machines are usually three-phase and may be arranged for any voltage or frequency, and the flywheels are designed to maintain the nominal frequency within close limits for a period of ten seconds with the alternator on full load.

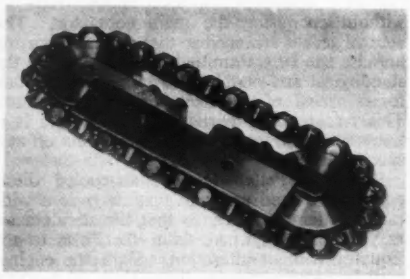
The use of a diesel-electric drive for the no-break alternator is comparatively novel, and although it appears mechanically inefficient, it is justified by the reduced possibility of any failure of power, as there is always a secondary power source available. The design of the system generally means that sizes of flywheels can be kept to a minimum, and as the continuity units are compact, they are easy to transport and install.

## Crossed-Roller Chains for Precision Slides

THE accompanying illustration shows an application of a roller chain of special design for use on precision machine tools made by the Skefko Ball Bearing Company, Ltd., in Sweden and recently described in detail in the *Ball Bearing Journal*. This chain consists of a series of cylindrical rollers, each of which is held in a pressed steel retainer, the retainers being pivotally connected together to form a flexible chain. To provide for loads acting in different directions the links are usually assembled so that the axes of rotation of adjacent rollers are at right angles to one another. These " crossed-roller " chains, as they are known, are made with links of six different sizes with rollers from 6mm to 24mm diameter and 5·8mm to 23·8mm long.



**Crossed-roller chains fitted on a machine tool slide**



Crossed-roller chain block for fitting on long-stroke machines

The chains are supplied in standard lengths of 20in, the smallest size having forty-two links and the largest twelve links.

In the typical application of crossed-roller chains to a machine tool slide, shown in the first photograph we reproduce, the chains are fitted between vee-shaped groove inserts. The top slide in this case has been moved back clear of the lower slide to show the end seal and scraper of plastic material or leather, which is fitted to prevent dirt getting into the slide members. In order to provide a means for pre-loading the rollers to give the maximum degree of slide rigidity, a slightly tapered adjustment strip can be fitted behind one of the groove inserts as in normal slide practice.

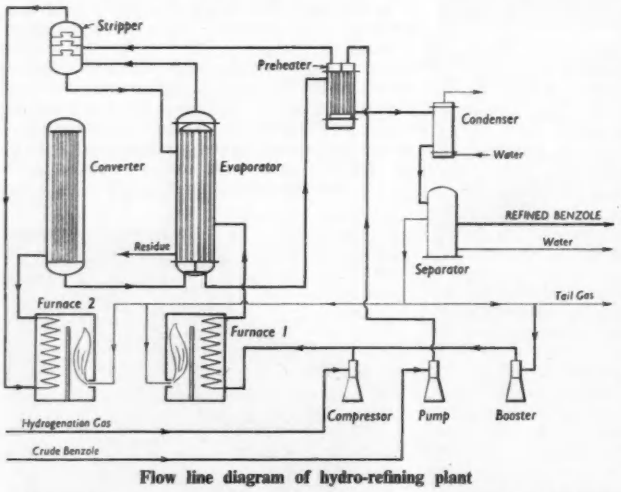
For long-stroke machines, where the moving part or table may have a considerable overhang, or where the slide is shorter than the stroke, a crossed-roller block, such as that in the second illustration, can be used. This block consists essentially of a short track member with two grooved pulleys round which an endless chain is mounted. Chain tensioning means are provided in the pulley brackets, and the pulleys are only used to guide the links of the chain, which is not supported along the back face of the block. A series of such blocks can be fitted end to end on each side of a slide on long-stroke machines.

## Refining Benzoles and Naphthas

RESEARCH carried out in recent years by the Coal Tar Research Association has resulted in the development of a process for the hydro-refining of crude benzole, naphthas and other hydro-carbon oils. Pure hydrogen or hydrogen-containing gases such as coal gas or coke oven gas, are employed in combination with a particular catalyst for the preferential hydrogenolysis of sulphur compounds, gum-forming olefines and colour-forming bodies, to give a substantially theoretical yield of refined products. The process has been developed for continuous operation which can be completely automatic and so ensure that the products are consistently as specified. This contrasts with the rather uncertain results obtained when using a batch or intermittent process of agitation with strong sulphuric acid. The latter system also results in some loss of spirit and the production of "acid tar," of which it is difficult to dispose. Furthermore, the new process employs a shorter contact time for crude benzole so that for a given size of converter a higher output is obtained, while for refining naphthas it operates at lower pressures. This results in a reduction in the consumption of hydrogen and minimises the undesirable conversion of aromatics to naphthenic hydrocarbons. A small laboratory scale unit has, up to the present, been used to ascertain the choice of hydrogenating gas and the general operating conditions suitable for the desulphurisation of a particular feed stock.

Commercial development of the process has been undertaken by Newton Chambers and Co., Ltd., Thorncliffe, near Sheffield, an agreement having been signed between the company and the Coal Tar Research Association. A pilot plant capable of dealing with 500 gallons of feed stock per day has been erected at the Thorncliffe works and can be used to determine optimum operating conditions and to gather chemical engineering data for handling crude benzoles and naphthas. The flow sheet which we reproduce illustrates diagrammatically the operations carried out in the plant. From storage tank the crude benzole is transferred to the plant by means of a pump which feeds the crude stock through a preheater and then a stripper and on to an evaporator. Here it is vaporised into the gas stream under carefully controlled temperature conditions. At the same time the hydrogenation gas is introduced in the evaporator after passing through a compressor and after receiving a certain amount of preheat in furnace No. 1. Carefully controlled conditions in the evaporator enable the residues fraction, consisting largely of wash oil "fronts" present in the crude benzole, to be removed as a liquid residue.

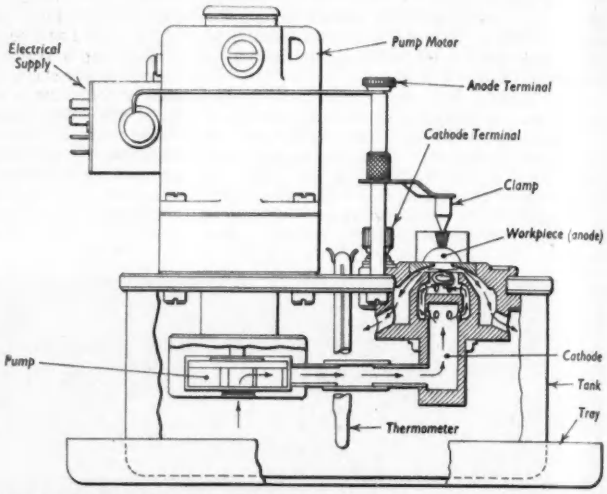
The gas stream, enriched with that fraction of the crude benzole required to be hydro-refined, passes through the stripper on its way to furnace No. 2, where it is preheated to the desired reaction temperature before being introduced into the converter. Afterwards, as indicated in the diagram, the heat content of the gas and refined benzole vapours is used to evaporate and preheat the crude benzole before the final cooling and condensation of the gas in the condenser. The condensate is passed on to a separator to produce refined benzole, water and tail gas. It is generally more economic to recycle the major part of the latter into the plant by means of a gas booster, irrespective of whether the hydrogenation gas be hydrogen or straight or modified forms of coal gas. Any fuel can be used for the furnaces, including tail gas, should its return to the works foul main not be possible. When coal gas is used for the hydrogenating medium the plant will be designed to operate at an approximate pressure and temperature of 450 lb per square inch and 750 deg. Fah.




Flow line diagram of hydro-refining plant

## Electrolytic Polisher

BASED on an apparatus developed by the Metallurgy Division of the Atomic Energy Research Establishment at Harwell,* an electro-polisher offered by the Shandon Scientific Company, Ltd., 6, Cromwell Place, London, S.W.7, is claimed to finish surfaces without flow lines, particularly on multi-phase alloys. Bubbles and the anodic layer are dispersed by a method which is said to be responsible for the freedom from flow lines; this is to pump the electrolyte through a series of orifices so that it forms a rotating and continuously renewed column touching the workpiece or specimen. As shown in our illustration, the electrolyte in the glass tank is transferred by a centrifugal pump into the cathode chamber. It then passes through two series of holes, drilled tangentially around the cathode, and forms a rotating column in the upper cathode chamber, where it impinges on the workpiece.




This drawing shows how the swirling electrolyte is used to remove gas bubbles and the anodic layer in the Shandon electropolisher. The centrifugal pump is stated to be made entirely of p.v.c. and polythene. The top of the electrolytic cell is the polishing and etching platform for the workpiece or specimen which rests on a removable p.v.c. mask. The mask has a circular hole defining the polishing area

All parts in contact with the electrolyte are reported to be made of glass, p.v.c., polythene or stainless steel. According to the maker's specification, the current from single-phase a.c. mains at 200V to 250V is fed into a steel cabinet 22in by 10½in square; there are two independent d.c. outputs and one a.c. output. The polishing supply is stated to be 50V d.c. at a maximum of 5A, or 60V at a maximum of 4·2A, in either case continuously variable from zero. The etching supply is given as 5V at a maximum of 0·5A, and is said also to be continuously variable from zero. The a.c. output is described as incorporating a rheostat, and is provided to drive the pump motor. The power supply system is arranged for manual or automatic operation, we understand, and in the former case all the outputs are controlled independently by on/off switches. Under automatic setting the controls are interlocked through relays: the pump motor is started by push button, and the polishing voltage is automatically applied for the desired period (from 1 to 90 sec., as determined by a time switch), after which both the motor and the d.c. supply are automatically switched off. Etching can be done at the end of the polishing period by switching over the supply.

PROJECTION DRAWING BOARDS.—A new stable projection drawing board for use on profiling machines incorporating pantograph reduction or tracing equipment is now manufactured in Britain by John Dickinson and Co., Ltd., Apsley Mills, Hemel Hempstead, Herts. These boards have a stretch-resisting aluminium foil sandwiched between two sheets of specially prepared high-grade paper. The boards are available in widths of 20in and 21in and can be supplied in any length.

* Sykes, Haddrell, Haines & Mott, *Journal* Inst. Metals, 1954-55, page 166.

# Industrial and Labour Notes

### The Industrial Outlook

In a statement which accompanies the annual report of Tube Investments, Ltd., the chairman, Sir Ivan Stedeford, urges that ways must be found of according capital investment in industry a high national priority of the kind that was given to housing after the war. Official policy towards capital expenditure, he says, has alternated between encouragement and discouragement; it seems to have been treated since the war like a tap which could accommodatingly be turned up or down. This may accord with theory, Sir Ivan remarks, but it cannot be reconciled with the conditions in which those responsible for production have to make investment and policy decisions, nor with the essential need for the country to keep abreast of its competitors.

Sir Ivan goes on to say it is hard to believe that it is unavoidable to change the official policies towards industry so often and so sharply. Is it impracticable, he asks, to give industry some broad assurance on which to plan, such as agriculture receives? There is room, he suggests, for an organisation at the centre which could at least try to forecast, for a few years ahead, the capital needs of the nation and then warn Ministers and the public, in good time, when plans incompatible with our economy were being shaped by public or private sectors of industry. Something on the lines of an advisory national investment committee, Sir Ivan claims, seems to be at least as important as the new advisory body for wages and prices.

### Wages and Disputes

On Wednesday of last week, the Minister of Labour, Mr. Iain Macleod, answered questions in the House of Commons about increases in earnings since 1951 and about the time lost through industrial disputes in the first seven months of this year. In reply to the questions on earnings, the Minister said that in the manufacturing industries generally in this country and in a number of non-manufacturing industries, average weekly earnings per manual worker were 45 per cent higher in April last than they were in October, 1951. Prices over the same period had risen by 24½ per cent.

As to industrial disputes, the Minister stated that the number of working days lost between January 1 and July 31 was 7,830,000. He said that 45 per cent of that total was lost in the coal mining, shipbuilding and ship repairing, water transport, docks and road transport industries. On the last available estimate, the Minister added, which related to the end of May, 1956, about 7½ per cent of the total civilian labour force of the United Kingdom was employed in those industries.

### Prices of Materials

The Board of Trade has stated that during October the average prices of basic materials used by manufacturing industry fell for the sixth consecutive month. They are now at the lowest level since the end of 1954. Jute was one of the few commodities to move upwards against the trend last month; amongst the commodities showing significant falls in price were non-ferrous metals except aluminium and nickel. Copper, which on average in October was 4·5 per cent lower in price than in September, rallied a little towards the end of the month.

The commodities covered by the price index of basic materials are those purchased from outside manufacturing industry and consist largely of imported materials. Index numbers which are influenced by the price movements of semi-manufactured goods have not experienced the sharp fall shown by the index for basic materials. Thus, the index numbers of materials used in the mechanical engineering industries, where purchases of iron and steel were important, are running at a much higher level than in any previous period, though this index has shown a slight fall in the last two months with the reduction in non-ferrous metal prices. Index numbers (June 30, 1949=100) at the end of October were 187 for materials used in the mechanical engineering industries; 179·4 for materials used in the electrical machinery industry, and 147·8 for building and civil engineering materials.

### Aircraft and Basic Industry

Sir Frank Spriggs, managing director of the Hawker Siddeley Group, announced last week that as a result of a three-year programme of expansion which was intended to render the group less dependent on orders for armaments, only 30 per cent of its activity was now devoted to aviation, instead of 80 per cent two years ago. The group employed 120,000 people, had assets of £214 million, and a turnover at the time equivalent to £260 million. Sir Roy Dobson, chairman of the firms in Canada, which had the same division between aircraft and total activity, stated that the Avro "Arrow" interceptor would gross 70,000 lb and exceed Mach 2. The supersonic fighter in England, the Hawker P.1121, had been "cocooned" awaiting an order after the prototype had been built on production jigs and tools; the design was considered to be satisfactory, and had been offered to NATO. In order to increase the participation in civil aviation, the group might build, say, a helicopter or an executive aircraft, British or foreign, under licence. They had also offered to supply short-range jet airliners to B.E.A. at a price that would not cover the £17,000,000 to £20,000,000 development costs.

### Iron and Steel

Steel production in Great Britain in October was slightly lower than in September; it averaged 437,800 tons a week. In answer to a Parliamentary question last Monday, the Paymaster-General, Mr. Maudling, said the Iron and Steel Board estimated that the output of crude steel in October was roughly 3·5 per cent below the actual maximum attainable in present circumstances. Over the first ten months of this year, however, steel output was 5·9 per cent higher than in the comparable period of 1956.

The Iron and Steel Board has stated that the coming into production of major new tinplate capacity, allied with some easing of demand, is hastening the withdrawal of hand mills and has led to the permanent closing of some obsolete steel-making plant previously engaged in the making of sheet and tinplate bars to feed the mills. Other steel-making plant of the kind has been changed over, for the time being, from bar to billet production. Pig iron production in October averaged 285,500 tons a week, compared with 282,700 tons in September; in the first ten months of this year output was 8·9 per cent above that of the corresponding period last year. Some falling off in the demand for foundry pig iron and in the iron requirements of the old steel plants already mentioned has resulted in certain blast-furnace capacity in the Midlands not being fully employed.

The Iron and Steel Board has also reported on steel deliveries to consumers and merchants during the third quarter of this year. The period, it says, was unaffected by any repercussions from the financial measures taken by the Government towards the end of September. Home deliveries of finished steel from United Kingdom mills totalled 3,067,800 tons in the third quarter, which was 6·7 per cent above the figure for the corresponding period last year. Exports by producers, at 595,800 tons, were 19·4 per cent higher than in the third quarter of 1956. The Board states that steel has continued to be developed at a higher level than a year ago to shipbuilding, coal mining, railways and constructional engineering. Deliveries to the motor-car, cycle and aircraft industries were 29·8 per cent higher in the third quarter than in the comparable period of 1956. Other consuming industries which took substantially greater quantities of steel in the third quarter included wire and wire manufacturers, deliveries to which had fallen in the first half of the year. The Iron and Steel Board adds that deliveries of plate, heavy sections, ferro-concrete bars and tinplate continue at much higher levels than those of a year ago.

### F.B.I. and European Free Trade

Last week, the grand council of the Federation of British Industries passed a resolution concerning the proposals for a European Free Trade Area. The main terms of this resolution are that the F.B.I. considers that the safeguards and conditions set out in the "joint report" (see THE ENGINEER, October 4, 1957) are essential to the interest of United Kingdom industry in a European Free Trade Area, and that the clauses in the convention dealing with the definition of origin of manufactured goods must provide for either or both the percentage content and the process method to be available at the choice of the industries concerned.

The resolution goes on to emphasise that existing anti-dumping legislation in the United Kingdom should be strengthened, and it is urged that the Government should use its influence to ensure that the other contracting governments equally provide adequate measures to prevent dumping in their own territories. The resolution also welcomes an undertaking given by the President of the Board of Trade that he will consult the Federation of British Industries in the course of negotiations in the event of any material change developing in the safeguards or conditions set out in the joint report.

# International Instrument Congress and Exhibition

No. I

*From November 2 to 10, the "Interkama 1957" (Internationaler Kongress mit Ausstellung für Messtechnik und Automatik) was held in Düsseldorf. This international congress, with exhibition of measuring instruments and automation, was the first of its kind to be held in Germany. Some 179 German and 149 foreign firms from eleven countries took part in the exhibition which, both by the way in which it was presented and by the interest which it aroused, must be regarded as a success.*

THE 1957 International Congress with Exhibition of Measuring Instruments and Automation (Internationaler Kongress mit Ausstellung für Messtechnik und Automatik—"Interkama") was held in Düsseldorf during the period November 2 to 10. It was the first event of its kind to be held in Germany. The double aspect of congress and exhibition was motivated by the idea that any measuring instrument must be seen in a dual way: as a member of a class of similar articles, the particular excellencies or faults of which are best gathered through comparison with others of its kind; hence the exhibition. On the other hand, there is the role which the instrument plays in relation to the whole of the plant—a role important not only from the technical but also the financial point of view, as shown by the fact that 7 to 10 per cent of the cost of a modern thermal power station is for instrumentation. These general aspects of instrumentation cannot adequately be dealt with by means of individual exhibits in a trade exhibition, but are suitable topics for a congress. In conjunction with the exhibition there was also run a number of special courses, about fifty altogether, arranged by firms in order to enable technicians to familiarise themselves with the special characteristics, manner of handling and in some cases the calibration, of various instruments.

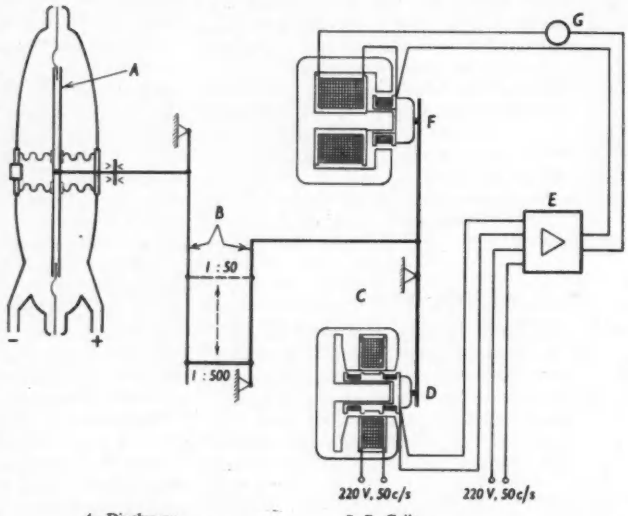



**Fig. 1—Transducer for flow measurements—Hartmann and Braun**

The congress was officially declared open on November 3, when Professor Dr. Vieweg, President of the Physikalisch-Technische Bundesanstalt (P.T.B.), Brunswick and Berlin, gave the welcoming address. Professor H. König, Bern, spoke to the theme "The importance of measurements for culture," and Professor Dr. W. Gerlach, Munich, gave a paper about "instrumentation and automation." During the technical sessions of the congress, which extended over the next four days, thirty-two papers were given, under the following groupings: general, electrical and process control measuring instruments and methods of measurements, regulators and methods of regulation in communications engineering, power control of boilers for compounding, and control in plants with batch processes.

The technical sessions were organised by the Verein Deutscher Elektrotechniker (V.D.E.) and the V.D.I./V.D.E. Control Technology group. As far as the exhibition, which opened on November 2, was concerned, it was not found possible to adopt any particular system of grouping the exhibits, as most firms manufacture a very wide range of equipment. In addition to the various firms' exhibits there were a number of representative stands covering 200, 350 or 400 square metres, on which the manufacturers of particular countries were exhibiting as a group. More than 300 firms belonging to the sphere of measurement and control technology—but excluding mechanical measuring tools—showed appliances and complete set-ups for measuring, regulating, control and automation. Of the firms taking part, 179 were German; in addition, contingents of about twenty to thirty firms each came from Italy, France, and the United Kingdom, followed by groups from Switzerland, the Netherlands, the United States, Belgium, Denmark, Canada and Austria and Hungary. The whole of the exhibition space amounted to about 24,000 square metres.

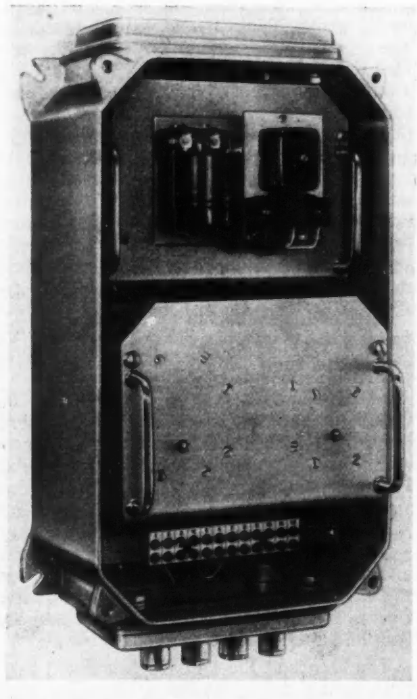


**Fig. 2—Millivolt transducer with cover removed, comprising (top rack) the photo-electric compensator unit, after Lindeck-Rothe, (bottom rack) the electronic amplifier—Hartmann and Braun**

Besides the general section, there were special displays dealing with the vocational training of precision fitters and instrument makers, rationalisation, standardisation, and maintenance of instruments. Special scientific-technological sections showed the history of metrology, units, standards and verification. These displays had been arranged by the German Museum at Munich, the Physikalisch-Technische Bundesanstalt (P.T.B.), Brunswick; the Standard Office North-Rhine-Westfalia, Cologne; and the German Rationalisation Board (R.K.W.), Frankfurt/Main.

### Hartmann and Braun A.G.

An extensive range of their manufactures and recent developments was shown on their combined stand by the firms Hartmann and Braun A.G., Frankfurt/Main, Schoppe and Faeser G.m.b.H., Minden/W., Elima Elektrische Messinstrumente G.m.b.H., Frankfurt/Main, and Günther and Tegetmeyer G.m.b.H., Brunswick. Although the classical electrical measuring instruments have a long history behind them, improvements are still being made in many directions, e.g. switchboard instruments are rendered more robust and insensitive to vibrations. High-precision instruments are being equipped with light pointers, and the use of mirror galvanometers outside the laboratory has been rendered possible by the construction of special damped suspensions.

Modern process control calls for the continuous registration of one or more of the physical quantities with which a particular process is concerned. These may vary widely; on the other hand, the cost of an installation is to a great extent dependent on whether large series can be produced. Besides being accurate and reliable, the control system should also be built up from easily interchangeable components. A novel system was shown for the first time by Hartmann and Braun, comprising transducers as well as electro-pneumatic control elements. The transducers are of the compensated variety, in order to make the obtainable accuracy depend solely upon the principle of measurement and not upon the transducer characteristic as is the case where deflections are measured. Our diagram, Fig. 1, shows the measurement of flow at low and medium pressure. The pressures from the two sides of an orifice plate are differentially applied to diaphragm *A*, the resultant deflection being transmitted through levers *B* to the transducer *C*, where it is converted into an a.c. voltage (coil *D*). This voltage is electronically amplified (*E*), the output of 0mA to 20mA d.c. being fed back to coil *F* in series with the indicating instrument *G*. Maximum deflection of the balance beam is 0·5mm, while the lever ratio can be varied between 1 : 50 and 1 : 500. The output resistance can range between 0Ω and 5000Ω, so that a great variety of recorders and controllers can be connected without special matching. The electromechanical components are mounted in explosion-proof housings; the usual mains voltage fluctuations are compensated. The same method can be adapted for the measurement of pressures from 10mm to 2500mm $H_2O$ and 0·35 kg to 1000 kg per square centimetre.

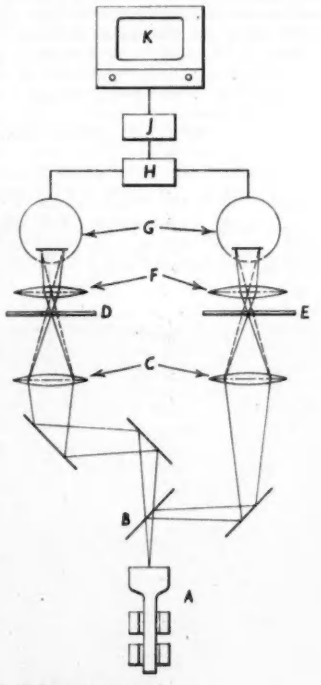
For temperature measurements the system provides a millivolt transducer with a minimum range of 0mV to 5mV, and for an output resistance of 0Ω to 5000Ω (Fig. 2). Unit indicators and recorders for 0mA to 20mA d.c. are provided for connection to all transducers, while a 0mA to 10mA d.c. integrating meter with shunt is used for measuring flow quantities. For controlling purposes there are provided a proportional magnetic-electronic amplifier and electronic time delay, the time constant of which can be adjusted between 0·05 to 20 or 0·15 to 60 minutes. There are also provided a constant-current mains unit, a two-stage magnetic power amplifier, various control drives and an electro-pneumatic controller. For studying the behaviour of proposed control circuits, an electronic simulator with ten integrating stages has been designed.

*(To be continued)*

## Evaluation of Variable Star Photographs

Variable stars, i.e. stars which vary in brightness, are of interest to astronomers because their distance from the earth can often be determined. The basic method of detection is to compare two photographs of the same sector of the sky taken at different times when brightness differences show up principally as differences in the diameter of the image. To determine which of the hundreds of images were different on the two plates was a difficult task which could be solved in a not very reliable manner by using the blink-microscope. This instrument shows the two plates in turn, so that variable stars appear to grow and shrink while others remain unchanged. It is, however, easy to overlook small variations in brightness, with the result that repeated counts often yield different numbers. Another method for the discovery of variable stars is to superimpose a positive of one plate upon the original negative of the other, when identical but reverse images cancel each other while differing ones remain visible. A great amount of care is, however, required to prepare suitable plates.

Recently, a method has been developed by the Kapteyn Astronomical Laboratory, University of Groningen, which makes use of a television technique* for scanning and electronically superimposing the two images. As the accompanying illustration shows, the photographic negatives *D* and *E* are scanned by the flying-spot scanner *A*. The optical system, which is symmetrical for the two plates, comprises two lenses *C* and four mirrors, the mirror *B* nearest to the scanner tube being half silvered. Optical reduction of the spot image is 1 : 10. Condenser lenses *F* project the images on to photo-multiplier tubes *G*. The difference of their electric output is amplified (*H* and *J*) and fed to the picture tube of a normal television set *K*, which operates in synchronism with the scanning tube. The chance of detecting a variable star by this means is stated to depend upon both its brightness and the difference between the two photographic images. Besides being more sensitive than the blink-microscope, the new method is also quicker. It can be used for the detection of astronomical bodies which move in relation to the background of fixed stars, e.g. asteroids. Other applications outside astronomy which suggest themselves are the detection of forgeries, e.g. of banknotes and differences in aerial photographs made at different times.




*A*—Flying-spot scanner tube.
*B*—Half-silvered mirror.
*C*—Lenses.
*D, E*—Star photographs (negatives).
*F*—Condenser lenses.
*G*—Photo-multiplier tubes.
*H, J*—Subtraction of outputs of photo-multipliers, amplification of difference.
*K*—Television set.

**Scanning method for the detection of variable stars**

* J. Borgman, *Philips Technical Review* 19 (1957-58), No. 4, page 140.

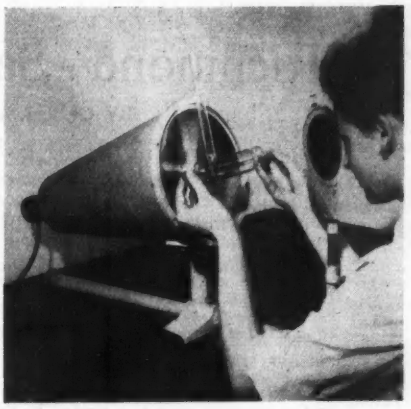
## Portable Frame Bevelling Machine

In the illustration below we show a portable frame bevelling machine which has a capacity for equal angles of up to 200mm by 200mm by 20mm. As stated by the maker, Schiess A.G. Düsseldorf (agent, Burton, Griffiths and Co., Ltd., Kitts Green, Birmingham, 33), the machine is designed for the hot bevelling of any kind of frame used in the shipbuilding industry, such as angles, bulbs, Z-bars and channels, from 90 deg. to 135 deg., and for the closed bevelling of any section from 90 deg. to 60 deg. The capacity is indicated by the following figures:

| | | | | |
|---|---|---|---|---|
| Equal angles ... ... | From | 80 × 80 × 10mm | to | 200 × 200 × 20mm |
| Unequal angles ... | From | 120 × 80 × 10mm | to | 200 × 100 × 18mm |
| Bulb angles ... ... | From | 150 × 75 × 13mm | to | 300 × 95 × 18mm |
| Channels ... ... | From | 200mm | to | 400 × 110 × 15mm |
| Z-bars ... ... ... | From | 180mm | to | 200 × 90 × 13mm |

It is also possible to alter the bevelling angle of the plates with the frame running through the machine, at the rate of 11 deg. per metre. Besides hot bevelling, the machine can carry out cold bevelling of sections up to about half the sizes quoted above.

The machine frame is welded and has been designed for great rigidity. There are two sets of rolls, one stationary in relation to the frame, and another which can be swivelled in a circular housing to the angular position required for bevelling. Each of the rolls of this second set is driven by a 20 h.p. reversible motor, both motor starters being coupled together. Any wear of the rolls is taken up by wedges so as to maintain the apex of the bevel. The gaps are adjustable to suit the frame thickness. Another motor, of 15 h.p., and provided with a built-in brake, serves for setting the angular position of the bevelling rolls, and also for driving the capstan shown in our illustration, as well as the carriage of the machine. The capstan is used for feeding the sections to the machine, and for charging the furnace. Both the bevelling angle and the length of frame already bevelled can be read off by the operator at his stand, an arrangement which facilitates the production of frames with varying bevel. The operating speed of the machine is such that even frames of great length can be bevelled and subsequently bent on the slabs in one heat.

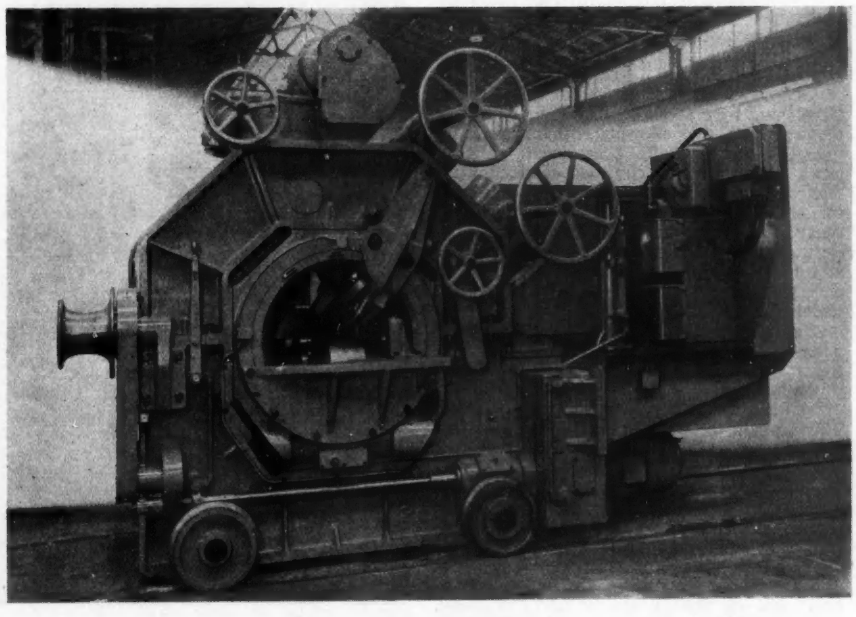


**Optical strain tester with 210mm diameter light source and 95mm diameter analyser**

## Optical Strain Tester

The accompanying illustration shows a strain tester for checking for the absence of strains in transparent materials, and joints between glass and metal. The instrument, which is made by Carl Zeiss, Oberkochen, is handled in this country by Degenhardt and Co., Ltd., 32, Maddox Street, London, W.1.

The instrument comprises a casing in the shape of a truncated cone, mounted on a stand, with its axis slightly inclined to the horizontal. The base of the cone is a ground glass screen illuminated by polarised light. As the illustration shows, the object to be tested is held between this screen and the analyser which is mounted on an adjustable stand in such a way that both its height and its distance from the ground glass screen can be varied up to a maximum distance of 300mm. Light is obtained from a 6V, 30W bulb fitted with a special lens system, polarising filter and red-I quartz plate which causes the field of view to appear a deep purple. An even illumination of the 210mm diameter ground glass screen is obtained by means of a grooved Fresnel lens placed behind it. The brightness is such that tests can be carried out in full daylight. For testing small objects, the field of illumination can be decreased in size and correspondingly increased in brightness by moving a lever. The orientation of the quartz plate is such that tensile strains cause the colour of the image to change to yellow, while compressions cause a change towards the blue.



**Portable frame bevelling machine**

# Richmond - San Rafael Bridge

BY OUR AMERICAN EDITOR

No. IV—(*Concluded from page 729, November 15*)

*The Richmond-San Rafael Bridge connecting the towns of Richmond and San Rafael across the northern part of the San Francisco Bay in California, was opened to highway traffic on September 1, 1956. The main structure has a length of 21,343ft. A main and a secondary channel are each spanned by a three-span structure with, in each case, a 1070ft main span and two 535ft spans; vertical clearances above the channels are 185ft and 135ft, respectively. Initially, only the upper deck, of 36ft width, was opened; the lower deck, also of 36ft width, was completed in August, 1957, and the bridge now has six 12ft traffic lanes in operation.*

## Erection of Steelwork

THE bridge superstructure was erected by the joint venture prime contractor. A sub-contract was awarded to a pile driving contractor to construct four falsework bents. In addition to the engineering staff of the contractor, the consulting firm of Earl and Wright, San Francisco, was engaged by the contractor to design the special equipment and to investigate and check the erection plans.

Of the thirty-six 100ft girder spans, the twenty-six over water were placed by derrick barges and the ten over land at the Richmond end were erected with truck cranes. The largest girders were 125ft long and weighed 24½ tons. All rivet holes were punched or drilled full size, and no reaming was required during erection. All of the steel bents and braced towers are situated on water piers and were erected with derrick barges. The legs of bents or braced towers less than 100ft high were erected as a unit, i.e. each leg was placed on the pier and the transverse bracing was then set and bolted. The procedure was first to grout the anchor bolts within the pipe sleeves to their exact position, and then to lower the bent or tower element complete with baseplate over the anchor bolts to rest upon the concrete pier top, which had been ground and then coated with a heavy paste of red lead and oil. Following the temporary bolting and pinning of the bracing, the holes were reamed to size and rivets driven. Towers over 100ft high were erected in two sections.

The 289ft truss spans were erected by two methods. The lower spans, consisting of one on the west approach and seven on the east end, were erected on cribbing on barges alongside the painting and shipping yard, and then floated to their respective sites. As the tide ebbed the trusses were lowered into position and this process was accelerated by flooding the barges. The trusses were then pinned to the pier shoes.

The remaining 289ft spans were erected on the aluminium falsework trusses described previously, which were placed on timber bents resting on the concrete piers and partially tied to the permanent steel bents. The timber bents were of such height that the top chords of the aluminium spans were about 4ft below the bottom of the steel span, thus allowing sufficient room for operating the specially constructed hydraulic jacks. The procedure consisted of erecting the steel truss members on the jacks. An erection traveller crane was used for this operation, the steel being lifted from freight barges. The elevation of the steel on the aluminium truss was adjusted by the jacks to compensate for falsework deflection, which totalled about 11½in at midspan under full dead load. Mechanical locking nuts on the jacks protected against hydraulic failure. After the tension or lower chord of the steel truss was riveted together and 50 to 75 per cent of the holes in the upper chord had been pinned or bolted, the hydraulic jacks were released. This brought the top or compression chords of the steel truss into bearing, and they were then riveted. Upon completion of the truss erection the traveller crane lowered both ends of the aluminium falsework span upon barges to await its next use. This lowering was accomplished by a system of sheaves and rigging.

The erection of steel was a continuous process. The aluminium truss under the last completed steel span was floated into the next bay ahead, and the traveller crane proceeded along the newly erected permanent steel to lift the aluminium span to its new position. However, the sequence of erection of the 289ft spans was dictated in part by the design provisions for handling longitudinal forces. These forces are transmitted along a series of the 289ft spans, supported on flexible bents to an end tower which was rigidly braced to transfer them to the foundation. Thus the erection of the 289ft spans had to commence at these braced towers and proceed in either direction toward the expansion bents, where maximum movement occurs. The fixed towers for the 289ft spans are at piers Nos. 19, 30, 44, 55 and 61.

## Erection of Navigation Spans

As mentioned previously, there are two cantilever spans over the navigation channels. Each of these spans, except for vertical clearances over their respective channels, are identical, having a main span of 1070ft, centre to centre of piers, and anchor arm spans of 535ft. The erection method chosen by the contractor called for constructing on the main cantilever piers an inclined bent extending to the second panel point of the anchor arm and the erection of steel for the anchor arm thereon. The erection of the anchor and cantilever arm steel was balanced about the tower, with the inclined bent acting as a stabilising arm until the erection progressed to a falsework bent situated in the centre of the side channel. Thereafter the anchor arm was completed to act as a hold-down member, while the main span was extended without falsework from each main pier to join at midspan.

The preliminary steps involved in this method of cantilever erection were: (1) erecting an inclined temporary bent, supported on the pier and attached to the cantilever tower; (2) constructing the temporary falsework erection pier at the midpoint of each side channel; and (3) placing a temporary steel erection tower on the falsework pier. The first structural steel members, consisting of the bottom chords, lower verticals and diagonals in the first two truss panels of the anchor arm, were placed between the cantilever tower and the inclined bent by a floating derrick. After the appropriate lower deck members of the floor system had been placed, a traveller derrick crane was placed on the cantilever arm. Cantilever erection was then accomplished by these two derricks working in opposite directions from the main tower.

After erection had progressed on the cantilever and anchor arms sufficiently to induce tension in all of the upper chord members between the falsework bent and the main tower, the inclined bent was dismantled and re-erected at the opposite tower. The falsework bent beneath the anchor arm was not removed until this arm was completed to the next permanent bent. Longitudinal adjustment at the ends of the anchor spans was made by removing ties between the legs of the split bent and jacking the free leg to make the closure. The amount of jacking required for closure did not exceed 1½in.

## Painting the Bridge

Shop painting of the structural steel consisted of cleaning and prime coating the fabricated members. After erection, painting consisted of cleaning and spot coating the abraded areas

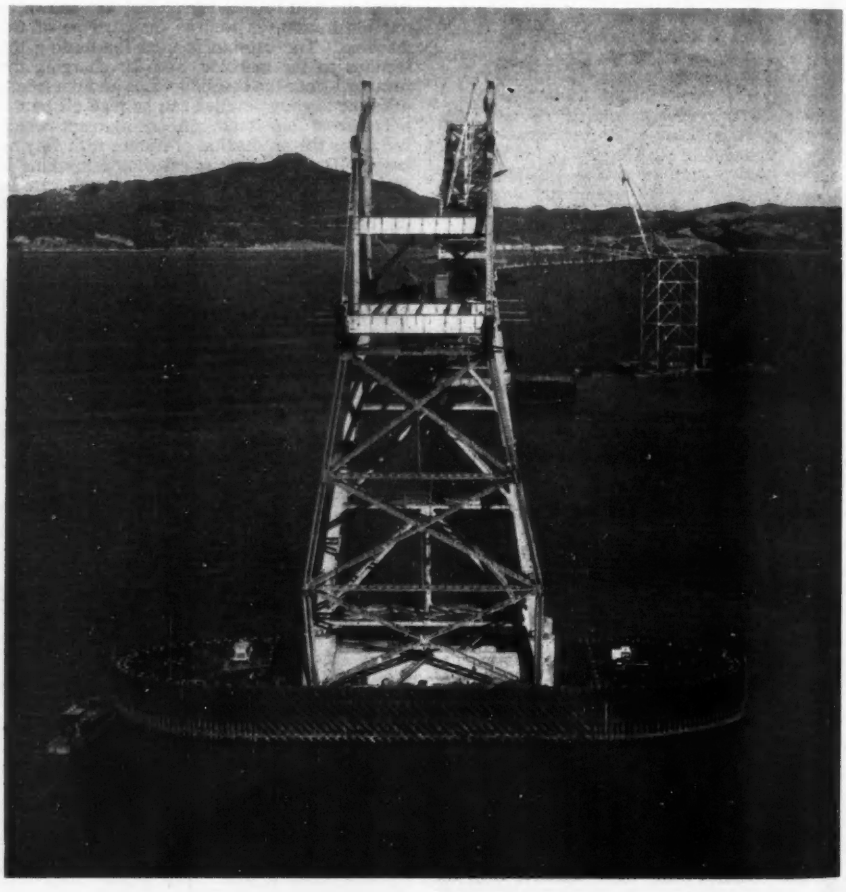


**Fig. 13—Erection of cantilever span, with travelling derrick crane being used to place steelwork from a main tower**

and riveted connections, and applying the second and third coats of paint.

After fabrication and in preparation for the prime coat of paint the steel members were cleaned of rust and loose mill scale in accordance with the specifications, which permitted the use of power wire brushes. In view of this, the contractor elected to clean by wire brushing members consisting of or fabricated from new mill steel, and by sand blasting members inaccessible for wire brushing or fabricated from weathered steel having considerable surface rust. Members in the plate girder spans, bents and towers, except cantilever towers, truss span floor beams and approximately two-thirds of the stringers, were cleaned by power wire brushing. The remaining structural members, consisting of the towers for the cantilever spans, the main members for the cantilever and truss spans, transverse bracing, and kerb and railing elements, were cleaned by sand blasting. The eyebars are an exception to the above cleaning requirements, in that they were sand blasted to remove all mill scale. This was deemed advisable since they were coated with heavy mill scale resulting from heat-treating. Future cleaning of these bars will be difficult due to the close spacing after erection.

Following the cleaning operations, the prime coat was applied by spraying and brushed out on the accessible surfaces. After a drying period of three to five days, the members were examined and thin areas were covered by hand brushing and an additional coat brushed along the seams and around rivets. The second and third coats of paint were applied after erection with the second coat put on by spraying and the accessible areas brushed out by hand. The aluminium finish coat was sprayed on without further brushing. All paints were formulated and mixed by the paint manufacturer and delivered to the job in sealed 5-gallon containers except the aluminium paint which was mixed just prior to use.

For painting the 100ft plate girder spans, two scaffold units were employed. The first consisted of a full width bottom scaffold travelling on the permanent scaffold rails to paint the underside of the girder spans. To paint the sides and other areas, the second unit consisted of two overhanging scaffolds, which rolled along the concrete deck and were built so that they extended down over the outside of the railing. The equipment used in painting the 289ft truss spans, of which there were three sets, consisted of both the upper and lower deck horizontal scaffolds travelling on the permanent rails and two side scaffolds that extend the full depth of the trusses travelling on angle rails on the top chord and spaced by horizontal rollers on the bottom chord. The towers and vertical elements of the cantilever span were reached by boatswain chairs supported from above.

### Concrete Deck

The roadway deck of the bridge is a reinforced lightweight concrete slab. The slab is 36ft wide and has a depth of 10½in on the plate girder spans and a depth of 6in on the truss and cantilever spans. The lower or structural portion of the slab is lightweight concrete having a cement content of six and a half sacks of cement per cubic yard and designed for a dry weight of 103 lb per cubic foot. Test cylinders have indicated compressive strengths of 3000 lb per square inch at twenty-eight days. The top ½in wearing surface of the slab is a natural sand concrete consisting of 1 part cement to 3 parts natural sand. Approximately 14,200 cubic yards of concrete and 1400 tons of reinforcing steel were required for the deck. Lightweight aggregates in three sizes were supplied for the easterly portion of the bridge under the trade name of "Basalite," and for the westerly portion under the trade name of "Haydite." Both materials were expanded shale aggregates, one being formed in sized pellets prior to calcining and the other crushed and graded following calcining.

The mould and scaffold work consisted of two kinds, one for the girder spans and the other for the truss and cantilever spans. On the girder spans the first item of work consisted of constructing an entire deck for the carpenters and other workmen under the portion of structure being worked upon. This working platform was supported by transverse welded steel pipe trusses 40ft long, hung from the lower flanges of the plate girders. These were placed at 6ft centres and extended for a distance of 1500ft. On these trusses 2in by 8in timber ribbons were then placed and wired at 4ft centres. A length of 600ft to 800ft was then decked with ¾in plywood to provide a working platform. The girder span mould work was supported by three longitudinal rows of 25ft steel beams at 6ft centres between and parallel to the plate girders, and hung by U-bolts from the floor beams and diaphragms. There was also one row of braced steel beams under each kerb line. These outside girders also supported the concrete placing and finishing equipment. A timber nailing sleeper was then placed on the steel beams, over which 2in by 6in transverse timber joists at 12in centres were then laid. These joists were covered with ¾in plywood mould panels. To provide camber to compensate for the deflection of the steel beams, shims were placed under the sleepers.

The slab moulds for the cantilever and truss spans, in general, consisted of ¾in plywood panels supported by the permanent floor stringers. The construction scaffolds were supported from the steel tracks which were provided for the maintenance gantry.

Deck concrete was mixed and hauled to the site in transit mixers. Powered concrete buggies were used to transfer the concrete from the trucks to the moulds. Screeding and finishing the concrete deck was the final operation. Two mechanical finishing machines were used for vibrating and surfacing the concrete deck, one for the lower structural portion and the second for the topping or wearing surface. Each machine was of similar construction, except that the second strike board or screed was raised ½in for the wearing surface. These machines were constructed especially for the work and were designed to run on the permanent kerb channels which, in effect, acted as rails. Each machine consisted of a 36ft screed equipped with mechanical vibrating units. The concrete was vibrated in place during the first operation. Successive kneading and screeding passes were made to obtain the desired surface finish. The second machine operated in a similar manner on the topping or wearing course.

The final finishing and applying of the curing compound was performed by a third machine equipped with power-operated brooms and spraying equipment. The power-operated brooms consisted of brush units mounted on a transverse circular belt. Thus, in operating the belt a permanent, skid-resistant, transverse texture was brushed into the concrete. The curing compound was applied by two transversely operated nozzles. By combining the forward motion of the machine and the transverse motions of the nozzles, a uniform coating of curing compound was applied to the pavement.

Two maintenance tracks or rails were provided under each deck throughout the steel portion of the bridge. From these tracks were suspended travelling maintenance gantries, or platforms, for use by the painters and for their supplies. Additional tracks for side gantries were provided on each of the upper chords of the 289ft spans. During construction the side gantry tracks were used by painters and other construction workers.

The steel kerb plates of the bridge have a half-round contact surface. This kind of kerb has been widely used on California State Highway bridges and has been found to be very effective in preventing the wheels of vehicles from climbing the kerb when hitting the latter with a glancing blow. The steel kerb plates are removable throughout the length of the bridge to facilitate repairs or the addition of new utilities. A 6in continuous clear opening between the underportion of the kerb and the concrete slab affords free drainage of deck water in wet weather. Wind blows most of the road grime off the deck through the opening. When the roadway is cleaned periodically by mechanical means, the roadway dirt can be brushed or washed through the opening and over the side of the structure.

### Toll Collection

Of great importance in planning the structure was the collection of tolls, constituting the only source of revenue to repay the bridge revenue bonds. Special attention was given to the design of a complete and functionally integrated toll collection facility which would achieve an accurate and dependable means of ascertaining that all revenue is properly reported and maximum efficiency of operations at the toll plaza is obtained.

Electrical and mechanical devices were designed to be interlocked so that the toll collection equipment will function only in accordance with a definite procedure. The toll collection equipment consists of a co-ordinated assembly of devices necessary for the remote electrical registration of the tolls collected and the vehicles passing through the toll lanes. All collections are made from the driver's side of the vehicles and all toll lanes can be used for mixed traffic. To protect the motorist and the toll collector from charges of static electricity that accumulate on moving vehicles, "static eliminators" have been installed in the concrete slab between the toll booths.

The three centre booths on each side of the toll plaza have duplicate sets of collection equipment: their operations could be reversed to accommodate traffic during peak hours during the period when only one deck was in operation. Now that the approaches at the Point San Quentin terminus have been completed, the bridge is open to unidirectional traffic on both decks. West-bound traffic proceeds by the upper deck, while east-bound traffic uses the lower deck. Thus, there are eight toll lanes for each three lanes of bridge traffic.

Funds for constructing the first stage or upper deck of the bridge were obtained in February, 1953, from the sale of an issue of Series A Richmond - San Rafael Toll Bridge Revenue Bonds in an amount of 62,000,000 dollars. Of this amount, 50,000,000 dollars were set aside for first-stage construction, as required by the bond resolution. The total issue authorised by this resolution was 72,000,000 dollars; however, the remaining 10,000,000 dollars could not be sold until traffic and revenue requirements had been fulfilled over a period of three years of bridge operation. With first-stage construction costs being lower than originally estimated, consideration was given to completing the entire Richmond-San Rafael bridge project under the initial construction programme.

On October 26, 1954, Governor Goodwin J. Knight, during an inspection trip to the bridge, issued a statement that it would be advantageous to the State and to the motoring public if the lower deck were to be constructed at this time. The Governor further stated that his administration would make every effort to effect construction of the lower deck under the present programme, and that studies would be made on methods of financing this work. Following the Governor's announcement, a study was made to determine the amount of money required to complete the project. This study indicated that approximately 6,000,000 dollars of additional funds would be necessary for this construction. The possibility of obtaining the money from the sale of additional bonds under the bond resolution was studied. This method was not used because of certain conditions contained in the resolution. Refinancing of the project was considered but was not adopted due to the excessive cost. After various other considerations, it was determined that a loan from the State School Land Fund could be obtained by the California Toll Bridge Authority. This arrangement authorised the Director of Finance and the California Toll Bridge Authority to enter into an agreement whereby money from the State School Land Fund might be invested, up to 6,000,000 dollars, for the purpose of completing the lower level of the bridge and approaches.

Both decks of the bridge were completed and opened to traffic on August 20, 1957, and the structure now offers three 12ft lanes in each direction. In the first year of operation, using only one deck, 2,600,000 vehicles made use of the bridge crossing. Traffic is expected to increase considerably beyond this figure in future years.

The Richmond-San Rafael Bridge was designed by and built for the Division of San Francisco Bay Toll Crossings of the California Department of Public Works. Mr. Norman C. Raab was the engineer responsible for this bridge project, and we wish to acknowledge his assistance in the preparation of this article.

# Personal and Business

## Appointments

MR. REGINALD FREDERICK HANKS, M.I.Mech.E., has been appointed a director of Parkinson and Cowan, Ltd.

MR. F. BAXTER has been appointed home sales manager for machine tools of A. A. Jones and Shipman, Ltd.

VOKES, Ltd., has announced that Rear Admiral J. E. Cooke, M.I.Mech.E., has joined the company in the capacity of consultant.

ASHWORTH AND PARKER, Ltd., has announced that Mr. Fred Hamer, chief engineer, and Mr. Ansill H. Smith, works superintendent, have been appointed directors.

MR. D. A. C. BENNETT, chief executive of the Dunlop Rubber Company's Brazilian manufacturing company, has been appointed overseas sales manager in London.

THE BRITISH PETROLEUM COMPANY, Ltd., has announced that Mr. Robert Paterson Smith has been appointed a director to fill the vacancy caused by the retirement of Sir Kenneth B. Harper.

MR. C. G. WOLSTENHOLME has been appointed head of the new Midland sales office opened by West Instrument, Ltd., 43, Factory Centre, Lifferd Lane, Kings Norton, Birmingham, 30 (telephone, Kings Norton 4412).

AIR COMMODORE SIR ARTHUR VERE HARVEY has been appointed chairman of Aero Research, Ltd., Duxford, Cambridge, and Ciba, Ltd., Horsham, in succession to Sir Raymond Needham. Sir Raymond Needham remains a director of both companies.

THE SECRETARY OF STATE FOR SCOTLAND has reappointed Colonel Sir John Crabbe and Sir Ronald Thomson to be part-time members of the South of Scotland Electricity Board until December 31, 1960, and Sir Jackson Millar to be a part-time member of the board until December 31, 1958.

WILLIAM BEARDMORE AND CO., Ltd., has announced that Captain Q. H. Paterson, M.I.Mech.E., has resigned as joint managing director, but will continue as a director in an executive capacity. Mr. P. M. Thomas, formerly joint managing director, has been appointed sole managing director.

THE SECRETARY OF STATE FOR SCOTLAND has reappointed the Rt. Hon. Thomas Johnston to serve as chairman of the North of Scotland Hydro-Electric Board for a further period until December 31, 1958. He has also reappointed Sir Hugh Mackenzie to serve as deputy chairman of the board until December 31, 1959, and Sir George McGlashan to serve as chairman of the consultative council until December 31, 1959. He has appointed Mr. John Jardine as a part-time member of the board until December 31, 1960, in place of Mr. G. R. Mackintosh, whose present appointment ends on December 31, 1957.

THE SHIPBUILDING EMPLOYERS' FEDERATION announces that Mr. G. C. Parker, the managing director of the Caledon Shipbuilding and Engineering Company, Ltd., has been elected president in succession to Mr. John Hunter, and that Mr. R. W. Johnson, the managing director of Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., becomes senior vice-president, while Mr. G. R. Towers and Mr. J. Rannie have also been appointed vice-presidents. Mr. G. Morrison, the managing director of the Greenock Dockyard Company, Ltd., and Mr. L. Redshaw have been elected chairman and vice-chairman respectively of the Works Conference Board.

THE UNITED STEEL COMPANIES, Ltd., announces that Mr. Langton Highton, managing director of Workington Iron and Steel Company, will relinquish this position on December 31, on completion of forty-seven years' service. He will continue to be a director of United Steel Companies, Ltd., and of its associated companies in Cumberland. Mr. T. S. Kilpatrick, director and deputy general manager at Workington, will be appointed director and general manager on January 1. Mr. D. R. Wattleworth, director and general works manager, is to retire on December 31, after fifty years' service. He will be succeeded as general works manager by Mr. T. Sanderson.

## Business Announcements

STEDALL MACHINE TOOL COMPANY has opened new machine tool show rooms at Carpenter Street, Manchester.

A. A. JONES AND SHIPMAN, Ltd., Narborough Road South, Leicester, states that its telephone number has been changed to Leicester 823222.

SIR ERNEST SMITH has resigned from the chairmanship of the Industrial Coal Consumers' Council, an office he has held since the formation of the council ten years ago.

THE ENGLISH STEEL TOOL CORPORATION, Ltd., Openshaw, Manchester, has opened new premises at 167, Dukes Road, Acton, London, W.3 (telephone, Acorn 5602–3).

MERCEDES-BENZ (GREAT BRITAIN), Ltd., 58, Camberwell New Road, London, S.E.5, has acquired additional showroom and works premises on the Great West Road.

L. A. MITCHELL, Ltd., chemical engineers, Manchester, has opened a London office at Portland House, 73, Basinghall Street, London, E.C.2 (telephone, Metropolitan 8321/2).

B.T.R. INDUSTRIES, Ltd., has announced the formation of a new group aero division, under the management of Mr. C. G. Erlam. The marketing unit of the new division will be Palmer Aero Products, Ltd.

GRIFFIN AND GEORGE, Ltd., Alperton, Wembley, Middlesex, states that its export sales manager, Mr. Oliver Gregory, left London on Tuesday, November 5, for a six-weeks' business trip to the Middle East countries.

THE ELGAR MACHINE TOOL COMPANY, Ltd., Hampton Road West, Hanworth, Feltham, Middlesex, has moved its office and showrooms to 172–178, Victoria Road, Acton, London, W.3 (telephone, Acorn 5555); its associated company, The Press and Shear Machinery Company, Ltd., has also moved to the same address (telephone, Acorn 5562).

KETAY, Ltd., Romford, Essex, in conjunction with Norden-Ketay Corporation, United States, has concluded a licensing agreement with the Société Anonyme Precilec, France, providing for the manufacture under licence, and sale, of Ketay and Norden-Ketay synchro and servo-mechanisms in France. and for the interchange of technical and manufacturing information between the three companies.

LONDON TRANSPORT EXECUTIVE announces that it has made available to the newly-formed Ceylon Transport Board the services of Mr. R. G. Hills, divisional engineer in the department of the chief mechanical engineer (Road Services), and Mr. W. P. Morgan, divisional superintendent in the department of the operating manager (Country Buses and Coaches). While in Ceylon they will act as advisers on matters referred to them by the Board.

## Contracts

BRITISH INSULATED CALLENDER'S CABLES, Ltd., has received an order for about 22,500 yards of 110kV, three-core impregnated pressure cable, which will have copper conductors of 0·2 square inch cross-sectional area and will be aluminium sheathed. The cable will be made in the company's Erith Works, Belvedere, Kent, and the supervisory and jointing services for installation of the cable will be provided by B.I.C.C. Construction (N.Z.), Ltd. The contract is worth about £186,000 and is due to be completed towards the end of next year.

## Miscellanea

MR. E. R. TOPE.—We regret to record the death of Mr. Edward R. Tope, which occurred in hospital at Yeovil on November 13, following a road accident. Mr. Tope had been, for some years, works manager and chief designer of E. V. Twose (Manufacturing), Ltd., Lowman Works, Tiverton.

SYMPOSIUM ON DEFECTS IN METALS.—A symposium on vacancies and other point defects in metals and alloys is being arranged by the Metal Physics Committee of the Institute of Metals. It is planned for December 9 and 10, and is to be held at Harwell. A basic registration fee of £1 5s. will be charged to all applicants, members of the Institute and others, and only registered persons will be admitted. Details of the meeting, with a registration form, are to be sent to members. Non-members should apply to the Secretary, Institute of Metals, 17, Belgrave Square, London. S.W.1.

UNDERGROUND GASIFICATION OF COAL.—The National Gas Board announces that a British team has been sent to the U.S.S.R. to study progress made in that country on the underground gasification of coal. Experiments were begun in this technique in this country in 1949, and a pilot plant at Newman Spinney is due to begin production by the end of next year. The team includes Dr. A. E. Balfour, the deputy head of the underground gasification department of Humphreys and Glasgow, Ltd., the company which is responsible for the British project on behalf of the Coal Board.

BRITISH GEAR MANUFACTURERS' ASSOCIATION.—The half-yearly technical meeting of the British Gear Manufacturers' Association was held in London on Tuesday, November 12. At this meeting the following four short papers were presented to provide the bases of technical discussions :—" Measurement of Pitch Errors," by Mr. P. Walker ; " The Relation Between Size of Hob and Size of Worm in Cutting Worm Wheels," by Mr. S. C. Purkiss ; " The Advantages and Disadvantages of the Hob With Inverted Teeth," by Mr. J. R. Hopkins ; and " Root Form and Root Clearance for Ground Gears and the Effect of Grinding on the Strength of Case-Hardened Gears," by Mr. W. J. Davies.

ASBESTOS CEMENT PIPE FITMENTS.—It is claimed that fitments for rainwater, soil and flue pipes can be moulded with greater accuracy than hitherto by use of an Italian process of which exclusive rights in the U.K. are possessed by the Universal Asbestos Manufacturing Company, Ltd., Tolpits, Watford, Herts. According to the description we have received, the process involves the packing of wet asbestos cement around a flexible rubber bag which is placed in a phosphor-bronze mould. The bag is inflated hydraulically, and after one minute the cement is said to be firm and dry. When the bag is withdrawn the fitment can be handled, and the maker says that it is ready for despatch within forty-eight hours. The product is claimed to be tougher than that of existing processes.

GEIGER COUNTER TUBE.—A new Geiger counter tube, claimed to give an extremely low rate of count in the absence of the test specimen, has been developed by The General Electric Company, Ltd., for the measurement of very minute radioactivity. It has a thin duralumin window 1in in diameter. The length of the anode wire has been kept to a minimum to reduce the response to any extraneous radiation, and the materials used in construction are stated to be free from radioactive contaminants such as potassium and lead, which might contribute to the background count. In order to obtain the minimum background response, the tube must be operated in a heavily shielded enclosure and surrounded by a ring of $\gamma$ counters. This " anti-coincidence network " ensures that stray radiation from outside is not recorded. It is reported that background responses as low as 0·4 count per minute have been obtained with this network, thus permitting extremely low activity to be measured.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Mr. N. Carter read his paper, " The Standardisation of Large Tankers " before the North East Coast Institution of Engineers and Shipbuilders on November 15. The paper gives an account of current methods adopted for the standardisation of work on tankers and a table indicates the range of ships built in recent years at one particular yard. The author touches upon prefabrication methods and goes on to discuss specifically a tanker of 65,000 tons deadweight. Major points concerning after body and fore body lines and the position of the longitudinal centre of buoyancy are stated and a table gives particulars of basis model, developed model and developed ship. The extent of the cargo oil tanks is defined and also the structure in way of them, and there are general references to accommodation and mooring arrangements, and the paper includes drawings showing displacement sections, power curves, an outline general arrangement, accommodation layout and mooring arrangements.

INSTITUTE OF MARINE ENGINEERS.—On Tuesday, November 12, Commander E. Tyrrell, R.N., presented a paper entitled " Heat Balance Calculations and Their Use in the Installation Design of Steam Turbine Merchant Ship Propulsion Machinery," before the Institute of Marine Engineers. The paper considers the effect of fuel consumption upon earnings and the building up of a replacement reserve and shows how heat balance calculations and economic analysis can provide the shipowner with essential information. Factors to be considered when making such calculations are enumerated and the whole problem is examined for a 11,000 s.h.p. set of turbine machinery, covering first cost, interest charges, maintenance and fuel consumption over periods of ten and twenty years. The steam turbine cycle, boiler efficiency and the regeneration cycle are discussed and the allowances and assumptions made for heat balance calculations are listed. Nineteen designs are considered and accompanied by the associated heat balance diagrams, and the data as calculated are set out in tabular form, which includes estimates of net profit, based on 320 day and 120 day years, with fuel at 200 shillings and 160 shillings per ton, for periods of twenty and ten years. A heat balance calculation is detailed in an appendix and a second appendix examines the question of the extra cost.

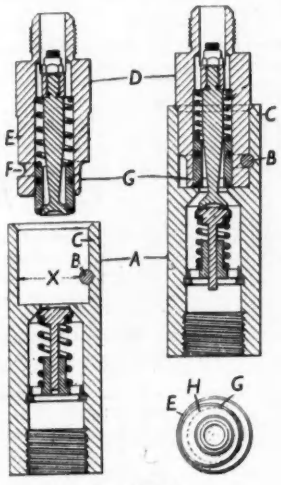
# British Patent Specifications

*When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.*

## TUBE AND PIPE COUPLINGS

**784,860.** May 12, 1954.—DETACHABLE PIPE COUPLINGS, Exactor, Ltd., Church Way, Edgware, Middlesex. (*Inventor: Cecil Norman King.*)

The invention provides an improved form of locking surface for pipe couplings which will be smooth in operation and easy to produce. Referring to the drawing, the socket part *A* of a coupling has a pin *B* in its wall *C* with part of its length across the bore.

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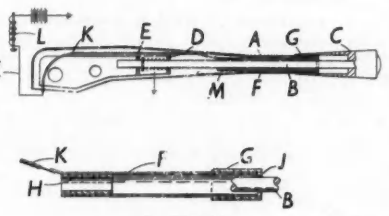
The spigot *D* of the coupling has a cylindrical spigot *E* which is a snug fit in the bore of the socket. Near its leading end this spigot is formed with a peripheral groove *F* corresponding to the section of the maximum projection of the pin *B* into the bore. This leading end of the spigot has a reduced diameter *G* eccentric to the spigot and extending over the groove *H* so as to leave the reduced end of the spigot with a maximum dimension corresponding to the dimension *X* between the pin *B* and the opposed wall of the socket *C*. Thus, when the spigot *E* is in a certain angular position relative to the socket and the pin *B*, it can be moved axially into the socket until the eccentric groove *F* registers axially with the pin. By now turning the spigot, the flank walls of the groove pass over the pin *B* so that the spigot and socket are locked to one another. The operation of inserting the plug into the socket unseats an automatic self-closing valve arranged in the socket or in the spigot or, as shown, in both depending on the requirements of any particular installation.—*October* 16, 1957.

## ROAD TRANSPORT

**785,365.** August 5, 1954.—GEAR CONTROL LEVER, Humber, Ltd., Stoke, Coventry, Warwickshire. (*Inventor: James Denne Batten.*)

The invention relates to manually operable control levers for change-speed gears, for motor vehicles, and is concerned with levers of the kind incorporating an electric switch which is operated by a lateral force applied to the lever for the purpose of engaging or disengaging a gear, before effective movement of the lever takes place. The switch may be employed to control a clutch or other component of a transmission system incorporating the change-speed gears. It is an object of the invention to provide a simple and effective construction of such a lever in which the switch is operable in whatever lateral direction the force is applied. Specification No. 614,658 describes an earlier form of lever to be mounted on the steering column of a motor vehicle. In the present construction shown in the drawing, the outer end *A* of the tubular hand lever is of increased diameter and is spaced away from the internal rod *B*. Furthermore, the interior of the bore of the knob *C* is of enlarged diameter to permit lateral movement of the knob in relation to the hand lever *A*. The support *D* for the inner end of the internal rod is also arranged to permit, by pivotal movement around the bearing *E* in the support, such lateral movement of the knob. Within the outer end of the hand lever there is a thin-walled brass tube *F* which surrounds the internal rod *B* and extends about half way to the bearing *E* for the inner end of the rod. This tube, which constitutes the tubular spring, is supported at its outer end by a bush *G* of insulating material fitted between the tube and the mouth of the hand lever. At its inner end the tube is lined with a similar bush *H*, which is a sliding fit on the rod *B*. At the outer end the mouth of the tube *F* is arranged to constitute an annular contact surface *J* which may make an electric connection with



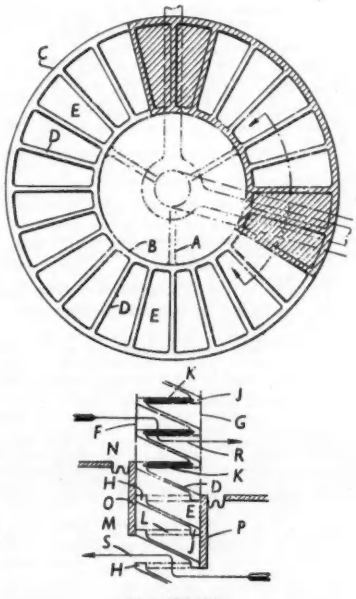

No. 785,365

the rod *B*, but is normally spaced from it. The rod is "earthed" and a connection *K* is taken from the tube *F* to the coil *L* of a solenoid for operating a clutch or to the coil of a relay which controls the clutch solenoid. In use the tube *F* serves to maintain the rod *B* in a central position out of contact with the contact surface *J* of the tube. If a lateral force is applied to the knob in any direction, the effect is to move the rod into engagement with the contact surface *J* of the tube, at the same time causing a lateral deflection of the inner end *M* of the tube and so creating a restoring force. The resistance to the movement of the rod which is offered by the tube is less than the resistance to movement of the lever and consequently the contact is made before the operation of engaging or disengaging a gear has begun. This result is achieved by a suitable selection of the thickness of the walls of the tube and of the unsupported length of the tube between the two bushes. The arrangement described has the advantages that there is no interference with the axial movement of the knob and rod required to release the reverse stop, any spark which may occur between the contact surfaces is masked by the lever and knob and that there is no risk of electric shock to the operator.—*October* 30, 1957.

## HEAT EXCHANGERS

**785,438.** February 16, 1953.—HEAT EXCHANGERS, The Superheater Company, Ltd., and John Charles Sayce White, both of 53, Haymarket, London, S.W.1.

Referring to the drawing, the heat exchanger matrix is of annular form adapted to be carried in an exchanger by a central spider *A* and it has inner and outer cylindrical walls *B* and *C* joined by a number of



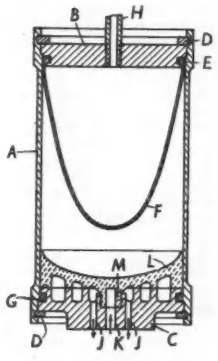

No. 785,438

radial partition walls generally designated *D*, which define between them an annular series of shaped ducts *E* for the passage of the working fluids from one face of the drum indicated at *F* to the other face indicated at *G* in the lower view. The partition walls *D* are inclined to the common axis of the two cylindrical walls of the drum to an extent equalling the width of a single duct *E*, such width increasing progressively radially outwards as will be appreciated from the zone bounded by the inner peripheral wall *B* on the inside to that bounded by the outer peripheral wall *C* on the outside. The radial edges of the partition walls *D* are flanged to provide enlarged sealing faces, the flanges *H* at the edges at one face *F* of the drum being on the opposite sides of the partition walls *D* to those *J* at the other face *G*, so that each complementary pair of flanges parallel with the axis of the drum provides a frame or seat for rectangular heat transfer elements, such as those represented at *K*, such elements having fluid passages and also being disposed parallel to the axis in one dimension and radial to the drum in the other. It will be seen that each duct *E* contains a heat transfer element *K* which extends between the radial partition walls *D* and occupies only a small fraction of the cross-section of the duct. The rear or inside of the sealing flanges *H* and *J* is conveniently grooved and the outer cylindrical member *C* is slotted as at *L* on its periphery so that the rectangular heat transfer elements *K* may be slid into position and held by a locking ring. The complementary sealing members provided on the ducts *M* and *N* at each face *F* and *G* of the matrix to isolate the respective fluids one from the other are also disposed radially and are indicated by the letters *O* and *P* respectively, and it will be noted from the upper view that the surface outline of each member suitably conforms to the overall shape of two adjoining ducts *E*. Maximum transverse sealing area between the faces of the drum and the walls separating the ducts is thus obtained without decreasing the cross-sectional area available for flow as represented by the arrow *R* for one working fluid and the arrow *S* for the other fluid. A modified arrangement of regenerator partition walls separating adjoining ducts is also shown in the specification.—*October* 30, 1957.

## HYDRAULIC MACHINERY

**785,454.** August 19, 1954.—HYDRAULIC ACCUMULATORS, The English Electric Company, Ltd., Queen's House, 28, Kingsway, London, W.C.2. (*Inventors: James Langley Russell and Eric Pottage.*)

The invention relates to hydraulic accumulators which incorporate a flexible gas-filled bag with separate liquid inlet and outlet ports and porous partition means separating the inlet port and the outlet port. The hydraulic accumulator shown in the drawing comprises a cylindrical casing *A* having end plates *B* and *C* attached by locking rings *D*. A seal is afforded between end plate *B* and the casing *A* by the rim *E* of the rubber bag *F* and a seal between end plate *C* and the casing *A* by the rubber ring *G*. A gas pipe *H* forms an inlet and outlet duct for gas entering the accumulator. The end plate *C* is ducted to provide outlet and inlet ports *J* and *K* respectively and a




No. 785,454

porous partition *L* of sintered bronze adjacent the end plate *C* has a projection *M* which separates the ports. The surface of the partition *L* which faces the rubber bag is smooth and curved so that it forms a rest for the bag. The partition prevents the bag from being trapped in the liquid outlet port and prevents particles carried by the liquid from entering the part of the accumulator which contains the rubber bag. An important feature of the construction shown is that the inlet port *K* is separated from the main chamber of the accumulator by a portion of the porous partition which has a relatively small area in comparison with the area of the part of the porous partition which separates the main chamber from the outlet port. Since the thickness of the partition is uniform, this results in the porosity of the partition in the inlet path being smaller than that in the outlet path. A modified construction is also shown in the specification.—*October* 30, 1957.

## Launches and Trial Trips

SAGAMORE, ore carrier ; built by the Blythswood Shipbuilding Company, Ltd., for Furness Withy and Co., Ltd.; length 482ft, breadth 67ft, depth 36ft 7in, deadweight 15,000 tons on 29ft draught ; service speed 12 knots ; three ore holds in the centre, ten wing tanks port and starboard ; three 150kW diesel driven generators ; Rowan-Doxford opposed piston, diaphragm oil engine, four cylinders 670mm diameter by 2320mm combined stroke, 4000 b.h.p., arranged to burn heavy fuel oil. Launch, September 12.

BHAGIRATHI, twin screw drag suction hopper dredger ; built by William Simons and Co., Ltd., for the Commissioners of the Port of Calcutta ; length between perpendiculars 350ft, breadth moulded 62ft, depth moulded 24ft, hopper capacity 3000 tons, filling time forty minutes, one 45in suction pump driven by a triple expansion engine, speed 12 knots ; two sets of triple expansion engines, steam supplied by four cylindrical multitubular boilers. Launch, September 26.

THESSALY, cargo liner ; built at Govan by Harland and Wolff, Ltd., for the Royal Mail Lines, Ltd.; length between perpendiculars 415ft, breadth moulded 58ft 6in, depth moulded to shelter deck 38ft 4in, gross tonnage 7300 ; three continuous decks, five cargo holds, one 30-ton and fourteen derricks to lift up to 10 tons, electric deck machinery ; three 150kW diesel driven generators ; Harland and Wolff two-stroke, single-acting, opposed piston turbo blown diesel engine, six cylinders, 620mm diameter by 1870mm combined stroke, 118 r.p.m. Trial, September 26.

## Catalogues and Brochures

PLOWRIGHT BROTHERS, Ltd., Chesterfield.—Illustrated leaflets describing plate feeder belts and mine car turntables.

REDIWELD, Ltd., 17/27, Kelvin Way, Crawley, Sussex.—Leaflet describing plastic tube manometers. A list of ranges and prices is included.

FRANK WHITELEGG, Ltd., 304, High Street, Sutton, Surrey.—Winding equipment bulletin "GCH," dealing with machinery for medium and heavy coil winding work.

CARTER GEARS, Ltd., Bradford, 3, Yorkshire.—Illustrated catalogue giving technical details of Carter "A" type hydraulic infinitely variable speed gears, with auxiliary equipment.

WILKINSON RUBBER LINATEX, Ltd., Camberley, Surrey.—Pamphlet illustrating and describing Linatex motor-driven diaphragm pump and the hand-operated diaphragm pump.

CHARRINGTON, GARDNER, LOCKET (LONDON), Ltd., Tower House, Trinity Square, London, E.C.3.—Catalogue giving details of the Charrington's metered fuel oil domestic and industrial delivery service.

INTERNATIONAL ALLOYS, Ltd., Haydon Hill, Aylesbury, Bucks.—Brochure commemorating the twenty-fifth anniversary of the start of production of the company's factory on the Slough Trading Estate in 1932.

## Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

### ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

*To-day, Nov.* 22.—STOKE AND CREWE BRANCH : Grand Hotel, Hanley, Stoke, Film, "Cables Round the World," 7.30 p.m.
*Tues., Nov.* 26.—SOUTH WALES BRANCH : Angel Hotel, Westgate Street, Cardiff, Film of the 1957 A.S.E.E. Exhibition, 7.30 p.m.
*Thurs., Nov.* 28.—SOUTH LONDON BRANCH : Greyhound Hotel, High Street, Croydon, "Branch Lecturettes," C. Hasler and H. T. Thorpe, 8 p.m.
*Fri., Nov.* 29.—COVENTRY BRANCH : Craven Arms, Coventry, Films on "Capacitors" and "Capacitors in Industry," 8.15 p.m.

### BRITISH INSTITUTION OF RADIO ENGINEERS

*To-day, Nov.* 22.—MERSEYSIDE SECTION : Technical College, Birkenhead, "Tropospheric Scatter System Evaluation," M. Telford, 7 p.m. ★ SCOTTISH SECTION : Department of Natural Philosophy, The University of Edinburgh, "U.H.F. F.M. Transmission," H. V. Sims, 7 p.m.
*Wed., Nov.* 27.—LONDON SECTION : London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, Annual General Meeting, 6 p.m., "Transmission Standards and Signal Distortion in Television and other Communication Systems," A. van Weel, 7.15 p.m.
*Fri., Nov.* 29.—SOUTH MIDLANDS SECTION : North Gloucestershire Technical College, Cheltenham, "Automatic Programming," P. M. Woodward, 7 p.m.

### ENGINEERING METROLOGY ASSOCIATION

*Thurs., Nov.* 28.—Northampton College of Advanced Technology, St. John Street, London, E.C.1, "The Work of the Metrology, Mechanisms, and Noise Control Division of the Mechanical Engineering Research Laboratory, Glasgow," C. Timms, 7. p.m.

### ILLUMINATING ENGINEERING SOCIETY

*Mon., Nov.* 25.—LEICESTER CENTRE : Demonstration Theatre, East Midlands Electricity Board, Charles Street, Leicester, "Road Vehicle Lighting," G. E. Charlesworth, 7 p.m.
*Tues., Nov.* 26.—LEEDS CENTRE : Yorkshire Electricity Board, Ferensway, Hull, "Exterior Lighting at a Modern Airport," J. Morse, 6.30 p.m.
*Wed., Nov.* 27.—LONDON CENTRE : Royal Institute of British Architects, Portland Place, London, W.1, "Planning the Interior : the Expression of Current Ideas and Requirements," B. P. Westwood, 6 p.m.

### INCORPORATED PLANT ENGINEERS

*Mon., Nov.* 25.—WEST AND EAST YORKSHIRE BRANCH : The University, Leeds, "Nuclear Reactors for Power Production," J. A. Dixon, 7.30 p.m.
*Tues., Nov.* 26.—SOUTH WALES BRANCH : South Wales Engineers' Institute, Park Place, Cardiff, "The Cement Gun in Use," W. J. Young, 7.15 p.m.
*Thurs., Nov.* 28.—SHEFFIELD AND DISTRICT BRANCH : Grand Hotel, Sheffield, "Factory Insulation—its Place in the National Economy," R. G. Hayes, 7.30 p.m.

### INSTITUTE OF FUEL

*Wed. and Thurs., Nov.* 27-28.—Institution of Civil Engineers, Great George Street, London, S.W.1, Second Conference on "Pulverised Fuel," 10 a.m. and 2.30 p.m.

### INSTITUTE OF MARINE ENGINEERS

*To-day, Nov.* 22.—MERSEYSIDE AND N.W. SECTION : Technical College, Bolton, "Engine Room Equipment," J. N. Cairns, 3 p.m. ★ SOUTH WALES SECTION : Swansea Technical College, Mount Pleasant, Swansea, "Modern Marine Steam Turbines," J. H Gooch, 2.15 p.m.

### INSTITUTE OF PHYSICS

*To-day, Nov.* 22.—S.W. BRANCH : Royal Military College of Science, Shrivenham, "The Field Emission of Electrons," F. A. Vick, 7 p.m.
*Wed., Nov.* 27.—LONDON AND HOME COUNTIES BRANCH : Royal Institution, 21, Albemarle Street, London, W.1, Symposium on "The Design of Physics Research Laboratories," 2.30 p.m.

### INSTITUTION OF CHEMICAL ENGINEERS

*Tues., Nov.* 26.—LONDON BRANCH : Royal Institution, 21, Albemarle Street, London, W.1, Symposium on "Recent Developments in Industrial Low Temperature Gas Separation," 9.45 a.m. and 2.15 p.m.

### INSTITUTION OF CIVIL ENGINEERS

*Tues., Nov.* 26.—Great George Street, Westminster, London, S.W.1, "The Design and Construction of a Dry Dock at South Shields for Messrs. Brigham and Cowan, Ltd.," D. F. Stott and L. M. Ramage, 5.30 p.m.

### INSTITUTION OF ELECTRICAL ENGINEERS

*To-day, Nov.* 22.—RADIO AND TELECOMMUNICATION SECTION : Savoy Place, London, W.C.2, Discussion on "Radio Observations on the Russian Satellite," 2.30 p.m. and 5.30 p.m.
*Mon., Nov.* 25.—RADIO AND TELECOMMUNICATION SECTION : Savoy Place, London, W.C.2, "Problems of Sound and Television Broadcasting Coverage," G. Millington, 5.30 p.m. ★ EAST ANGLIAN SUB-CENTRE : Assembly House, Norwich, "Germanium and Silicon Power Rectifiers," T. H. Kinman, G. A. Garrick, R. G. Hibberd and A. J. Blundell, 7.30 p.m. ★ MERSEY AND NORTH WALES CENTRE : Town Hall, Chester, "Earthing of Low and Medium-Voltage Distribution Systems and Equipment," F. Mather, 6.30 p.m. ★ NORTH EASTERN CENTRE : Neville Hall, Newcastle upon Tyne, "Electrical Equipment for Rectifier Locomotives," H. B. Calverley, E. A. K. Jarvis and E. Williams, 6.15 p.m. ★ SOUTH MIDLAND CENTRE, AND SOUTH MIDLAND RADIO AND MEASUREMENTS GROUP : James Watt Memorial Institute, Great Charles Street, Birmingham, "Magnetic Materials," F. Brailsford, 6 p.m. ★ WESTERN UTILIZATION GROUP : South Wales Electricity Board, Swansea, "D.C. Winder Drives Using Mercury-Arc Rectifier/Inverters," L. Abram, J. B. McBreen and J. Sherlock, 6 p.m. ★ READING DISTRICT BRANCH : George Hotel, King Street, Reading, "Cathodic Protection," J. H. Gosden, 7.15 p.m. ★ SOUTH MIDLAND CENTRE : Education Discussion Circle and Radio and Measurement Group, James Watt Memorial Institute, Great Charles Street, Birmingham, "The Teaching of the Subject of Magnetic Materials," F. Brailsford, 6 p.m.
*Tues., Nov.* 26.—NORTH-EASTERN CENTRE : City Hall, Newcastle upon Tyne, "The Electrification of the British Railways," G. H. Fletcher, 7 p.m. ★ NORTH-WESTERN SUPPLY GROUP : Engineers' Club, Albert Square, Manchester, "Earthing of Low and Medium-Voltage Distribution Systems and Equipment," F. Mather, 6.15 p.m. ★ SOUTH-WEST SCOTLAND SUB-CENTRE : Royal College of Science and Technology, George Street, Glasgow, C.1, "Servo-Operated Recording Instruments (A Review of Progress)," A. J. Maddock, 7 p.m. ★ RUGBY SUB-CENTRE : Rugby College of Technology and Arts, Rugby, "Transistor Circuits and Applications," L. P. Morgan, 6.30 p.m.
*Wed., Nov.* 27.—SOUTH-EAST SCOTLAND SUB-CENTRE : Carlton Hotel, North Bridge, Edinburgh, "Servo-Operated Recording Instruments (A Review of Progress)," A. J. Maddock, 7 p.m. ★ SOUTHERN CENTRE : City Council Chambers, Portsmouth, "The Measurement of Earth-Loop Resistance," G. F. Tagg, 6.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION : Visit to Medical Research Council, Hammersmith Hospital (Research Cyclotron), 5.30 p.m.
*Thurs., Nov.* 28.—SUPPLY SECTION : Savoy Place, London, W.C.2, "The Digital Computer Applied to the Design of Large Power Transformers," W. A. Sharpley and J. V. Oldfield, 5.30 p.m.
*Fri., Nov.* 29.—SOUTHERN CENTRE : South Dorset Technical College, Weymouth, "Equivalent Circuits of Transistors and their Application," L. E. Jannson, 6.30 p.m.

### INSTITUTION OF ENGINEERING DESIGNERS

*Sat., Nov.* 23.—N.E. BRANCH : Visit to Associated Lead Manufacturers, Ltd., Elswick, Newcastle upon Tyne, 10 a.m.
*Thurs., Nov.* 28.—38, Portland Place, London, W.1, "The Electrical Breakdown of Dissimilar Metals," G. Butler, 6.45 p.m.

### INSTITUTION OF MECHANICAL ENGINEERS

*To-day, Nov.* 22.—1, Birdcage Walk, Westminster, London, S.W.1 Technical Film Show, 6.45 p.m.
*Tues., Nov.* 26.—EASTERN BRANCH : Assembly Room, Town Hall, Luton, "Principles and Applications of Spark Machining," D. W. Rudorff, 7.30 p.m. ★ BIRMINGHAM A.D. CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, "Transmission Developments for Public Service and Heavy Goods Vehicles," A. Gordon Wilson, 6.30 p.m.
*Wed., Nov.* 27.—APPLIED MECHANICS GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Fretting Fatigue," 6.45 p.m. ★ EAST MIDLANDS BRANCH : Technical College, Lincoln, "Principles and Applications of Spark Machining," D. W. Rudorff, 7.15 p.m. ★ YORKSHIRE BRANCH : The University, St. George's Square, Sheffield, "Problems and Trends in Pressure Vessel Design," J. P. Duncan, 6.30 p.m. ★ EAST MIDLANDS GRADUATES' SECTION : College of Further Education, Green Close Lane, Loughborough, Film Show, 7.15 p.m.
*Thurs., Nov.* 28.—LONDON GRADUATES' SECTION : 1, Birdcage Walk, Westminster, London, S.W.1, "Some Aspects of Hinkley Point Project," R. E. Zoller, 6.30 p.m.
*Fri., Nov.* 29.—GENERAL MEETING IN CONJUNCTION WITH THE INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : "Recent Developments in the Manufacture of Castings," J. L. Rice, R. W. Ruddle and P. A. Russell, 6 p.m.

### INSTITUTION OF NAVAL ARCHITECTS

*Wed., Nov.* 27.—Institute of Marine Engineers, The Memorial Building, 76, Mark Lane, London, E.C.3, "The Nuclear Propulsion of Ships," Sir Christopher Hinton and R. V. Moore, 5.30 p.m.

### INSTITUTION OF PRODUCTION ENGINEERS

*To-day, Nov.* 22.—WALES SECTION : S. Wales Institute of Engineers, Park Place, Cardiff, "Recent Developments in the Control of Dust," W. B. Lawrie, 7 p.m.
*Mon., Nov.* 25.—MANCHESTER SECTION : Reynolds Hall, Manchester College of Science and Technology, Sackville Street, Manchester, "Machine Tool Development in the U.S.S.R.," N. Stubbs and P. Trippe, 7.15 p.m.
*Tues., Nov.* 26.—LUTON SECTION : Small Assembly Room Town Hall, Luton, Joint Meeting with Eastern Branch of the Institution of Mechanical Engineers, "Principles and Applications of Spark Machining," D. W. Rudorff, 7.30 p.m.
*Wed., Nov.* 27.—SHREWSBURY SECTION : Technical College, Shrewsbury, "From Diamond to Spark Machining," G. Fefer, 7.30 p.m. ★ WORCESTER SECTION : Cadena Cafe, Worcester, "Mechanical Handling," O. J. B. Orwin, 7.30 p.m.
*Thurs., Nov.* 28.—LINCOLN SECTION : Ruston Club, Lincoln, "Management and its Application to Maintenance Work," R. W. H. Maling, 7.30 p.m. ★ ROCHESTER AND DISTRICT GRADUATE SECTION : Sun Hotel, Chatham, Kent, "Application of Radio Isotopes in Industry," H. Seligman, 7.30 p.m. ★ CORNWALL SECTION : Camborne School of Mines, Camborne, Cornwall, Film on "The Technique of Copy Turning and its Development," 7.15 p.m.
*Sat., Nov.* 30.—NEWCASTLE UPON TYNE GRADUATE SECTION : Visit to Clarke Chapman, Ltd., Victoria Works, Gateshead, 8, 10 a.m.

### INSTITUTION OF STRUCTURAL ENGINEERS

*Thurs., Nov.* 28.—11, Upper Belgrave Street, London, S.W.1, "The Relationship of the Architect and the Structural Engineer," L. A. Chackett, 5.55 p.m.

### INSTITUTION OF WORKS MANAGERS

*Mon., Nov.* 25.—DONCASTER BRANCH : Danum Hotel, Doncaster, "Industrial Organisation in the Future," W. Brown, 7.30 p.m.
*Thurs., Nov.* 28.—GLASGOW BRANCH : St. Enoch Hotel, Glasgow, "The Art of Delegation," J. C. W. Stead, 7.30 p.m. ★ LANCASTER GROUP : Royal King's Arms Hotel, Lancaster, "Communications Within an Industrial Establishment," L. Beswick, 7.30 p.m.
*Fri., Nov.* 29.—NOTTS AND DERBY BRANCH : Sherwood Room, County Hotel, Nottingham, Joint Meeting with the Institute of Industrial Supervisors, "Educating the Boss," A. B. Waring, 7.30 p.m.

### JUNIOR INSTITUTION OF ENGINEERS

*To-day, Nov.* 22.—INFORMAL MEETING : Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Blowing of Blast-Furnaces," W. K. V. Gale, 7 p.m.
*Fri., Nov.* 29.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Annual General Meeting, 7 p.m.

### MANCHESTER ASSOCIATION OF ENGINEERS

*Fri., Nov.* 29.—Engineers' Club, Albert Square, Manchester, 2. "The Production of Motor Cycles," P. Walker, 6.45 p.m.

### NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

*Wed., Nov.* 27.—STUDENT SECTION : Mining Institute, Newcastle upon Tyne, Film Show, 6.45 p.m.
*Fri., Nov.* 29.—Mining Institute, Newcastle upon Tyne, Annual General Meeting, "Service Performance Trials Carried Out in the North Atlantic on the S.S. 'Cairndhu,'" S. L. Smith and R. E. Clements, 6.15 p.m.

### PLASTICS INSTITUTE

*Fri., Nov.* 29.—NORTH-WESTERN SECTION : Engineers' Club, Albert Square, Manchester, "The Machining and Finishing of Plastics," B. E. Terry, 6.45 p.m.

### ROYAL AERONAUTICAL SOCIETY

*Tues., Nov.* 26.—SECTION LECTURE : 4, Hamilton Place, London, W.1, "Some Aspects of Refrigeration in Supersonic Aircraft," E. J. Gabbay, 7 p.m.
*Wed., Nov.* 27.—GRADUATES' AND STUDENTS' SECTION : 4, Hamilton Place, London, W.1, "Flight-Testing Procedures at Supersonic Speeds," R. P. Beaumont, 7.30 p.m.

### ROYAL INSTITUTION OF GREAT BRITAIN

*To-day, Nov.* 22.—21, Albemarle Street, London, W.1, "Physics and the Astronomical Universe," W. H. McCrea, 9 p.m.

### ROYAL METEOROLOGICAL SOCIETY

*Tues., Nov.* 26.—Conference Hall, County Hall, London, S.E.1 "Weather in the Polar Regions," H. H. Lamb, 5.30 p.m.

### ROYAL SOCIETY

*Fri., Nov.* 29.—Burlington House, Piccadilly, London, W.1, Discussion on "Observations of the Russian Artificial Earth Satellite and Their Analysis," opened by H. S. W. Massey, 10.30 a.m.
*Sat., Nov.* 30.—Burlington House, Piccadilly, London, W.1, Anniversary Meeting, 2.30 p.m.

### ROYAL SOCIETY OF ARTS

*Wed., Nov.* 27.—John Adam Street, Adelphi, London, W.C.2, "William Blake—the Visionary Man," V. de S. Pinto, 2.30 p.m.

### ROYAL STATISTICAL SOCIETY

*Tues., Nov.* 26.—MEDICAL SECTION : Keene Lecture Theatre, Westminster Medical School, Horseferry Road, London, S.W.1, "Observer Variability in the Use of Respiratory Questionnaires," C. H. Wood and A. S. Fairbairn, 5.30 p.m.
*Thurs., Nov.* 28.—SHEFFIELD GROUP : Y.M.C.A., 49, Fargate, Sheffield, 1, "Some Problems of Long-term Research in Industrial Medicine," J. R. Ashford, 7 p.m.

### SHEFFIELD METALLURGICAL ASSOCIATION

*Tues., Nov.* 26.—B.I.S.R.A., Hoyle Street, Sheffield, Film on "The Habershon Planetary Mill," 7 p.m.
*Thurs., Nov.* 28.—JOINT MEETING WITH SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS AND IRON AND STEEL INSTITUTE : Room B.1, The University, St. George's Square, Sheffield, 1, Joint Discussion Meeting, 2.15 p.m. ★ HATFIELD MEMORIAL LECTURE : Firth Hall, The University, Sheffield, 1, "The Mechanism of the Formation of Banded Structures in Steel," P. Bastien, 6.30 p.m.

### X-RAY ENGINEERS ASSOCIATION OF GREAT BRITAIN, LTD.

*Wed. to Fri., Nov.* 27-29.—Royal Horticultural Hall, London, S.W.1, in conjunction with the Nineteenth Annual Congress of the British Institute of Radiology, an Exhibition of X-Ray Apparatus.

## Advanced Engineering Courses

**Operational Research.** UNIVERSITY OF BIRMINGHAM. Institute for Engineering Production, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. Residential executive course, Monday, November 25, to Friday, December 6. Fee £50.